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ASSESSMENT OF THE BIOLOGICALLY BASED LOW FLOW ANALYSIS TECHNIQUE

R. A. C. PROJECT NO. 408 C
FINAL REPORT

Environment
Ontario
Jim Bradley, Minister

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FINAL REPORT

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ASSESSMENT OF THE BIOLOGICALLY-BASED LOW FLOW ANALYSIS TECHNIQUE

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 Background and General

The goal of the Ontario Ministry of the Environment (MOE), with respect to surface water quality management is "to ensure that the surface waters of the Province are of a quality which is satisfactory for aquatic life and recreation" (MOE, 1984). As part of its mandate, the MOE is responsible for reviewing and approving applications to allow industries and municipalities to discharge effluent into receiving water bodies. Part of the approval process involves an assessment of existing point and non-point sources of pollutants, and historical flow records to determine the study area's wasteload allocation (WLA). The present WLA methodology involves defining critical low flows (for example, the hydrologically-based design flow $7Q_{20}$ - the 7-day average low flow occurring once in 20 years) which are used to measure the waste assimilative capacity of water bodies in order to meet Ontario Water Quality Objectives.

The MOE in conjunction with Cumming Cockburn Limited (CCL) has initiated this research study to investigate the merit of the existing design low flow methodology.

This research study is based on methodology developed as a result of a policy initiative of the United States Environmental Protection Agency (U.S. EPA, 1985) which involves the application of biological and chemical assessment techniques to control toxic pollution. The technique, developed by the Office of Research and Development, incorporates a two-number aquatic life water quality criteria (WQC). The two-number WQC defines the duration and frequency of low flows and concentrations which may result in acute or chronic toxicity levels in aquatic life.

2.0 HYDROLOGICALLY-BASED LOW FLOW DESIGN METHOD

2.0 HYDROLOGICALLY-BASED DESIGN FLOW METHOD

2.1 Background and Rationale

The conventional methodology used to determine design low flows for wasteload allocation purposes has involved the application of a statistical technique, which may indirectly account for biological factors or toxicity levels affecting aquatic life. However, few previous investigations have attempted to develop a rigorous basis for the MOE's current design criteria (the $7Q_{20}$ flow - seven-day low flow occurring once in twenty years (e.g. Logan, L.)). On the other hand, it is known that use of $7Q_{20}$ is conservative relative to other design standards ($7Q_{10}$ in the United States). Therefore, there is still some uncertainty in regard to the stringency of the current criterion (i.e. whether it is too conservative or not conservative enough).

2.2 Extreme Value Analysis

The determination of hydrologically-based design low flows involves the application of extreme value analysis. At a gauged location, average low flows can be determined for selected durations of time for each year of record. A statistical distribution and associated parameters are then used to represent the observed low flow characteristics. For example, the corresponding minimum average consecutive 7-day low flow can be determined for each annual record. The series of 7-day average annual low flows can then be ranked lowest to highest and an extreme value analysis undertaken using an appropriate theoretical distribution.

Previous investigations have found that the Gumbel III distribution has resulted in the best fit for extreme value analysis of low flows on most Canadian rivers (Condie and Nix, 1975). However, as is noted in a recent low flow study (CCL, 1988) and by Condie and Chang (1987), stations with large negative skewness are better fitted using the three-parameter log normal distribution.

The hydrologically-based design flows used for comparison purposes in this report are from the results of the low flow study undertaken by Cumming Cockburn Limited (CCL, 1988). A more detailed description of the extreme value analysis methodology used in this report is provided in Appendix B.

3.0 BIOLOGICALLY-BASED LOW FLOW DESIGN METHOD

3.0 BIOLOGICALLY-BASED LOW FLOW DESIGN METHOD

3.1 Background and Rationale

The U.S. EPA has undertaken a policy initiative which involves the application of biological and chemical assessment techniques to control toxic pollution. They have identified two important factors which must be accounted for when considering the effects of toxicity on aquatic life: the duration of adverse exposure and the frequency with which criteria are exceeded.

EPA's methodology for considering biological factors for wasteload allocation calculations may be summarized as follows:

> "Aquatic impacts are a function not only of magnitude, but also of duration and frequency with which criteria are exceeded. EPA's recommended criteria for both individual toxicants and whole-effluent toxicity are specified as two numbers: the criteria continuous concentration (CCC), applied as a four-day average concentration; and the criteria maximum concentration (CMC), applied as a one-hour average concentration. The frequency with which criteria are allowed to be exceeded depends on site factors" (U.S. EPA, 1985).

The allowed exceedances are intended to be small enough and far enough apart, on the average, that the resulting small stresses on aquatic organisms will not cause unacceptable effects, except in those cases when a drought itself would cause unacceptable effects (U.S. EPA, 1986).

3.2 Procedure

The biologically-based design flow method was developed for application of the CMC and CCC for specific pollutants or whole effluents for performing a wasteload allocation using steady state modelling. In the U.S. the EPA water quality criteria consists of three components; magnitude, duration and frequency. For each pollutant two levels of protection are developed. These levels of protection are based on acute effects and chronic effects. Magnitude, duration and frequency are then recommended for each level of protection.

Since steady-state modelling assumes that the concentration of pollutants in effluents and the flow of the effluent to be constant, it follows that the concentration of a pollutant within the stream (downstream of the effluent discharge) can be inversely proportional to stream flow. Concentrations of pollutants in streams may then be considered in terms of intensity, duration and frequency, the same components used in determining water quality criteria.

The biologically-based calculation model then makes full use of durations and frequencies that are determined from laboratory toxicity data. Maximum durations are specified for protection against acute (short term) effects and for protection against chronic (long term) effects.

To protect against acute effects the duration must be set at as short a time period as practicable. The EPA recommends a one-hour averaging duration period for the Q_{CMC}. For most streams the variation in flow from one hour to the next is small. For streams which are regulated, such as those affected by hydroelectric or irrigation projects, hour to hour variations may be very large requiring the use of hourly flow data. It should be noted that the model assumes that both pollutant concentrations and effluent flows are constant when in fact they may vary significantly from one hour to the next and under those conditions the duration should then be reduced.

To protect against chronic effects the duration must be short enough to maintain the concentration at or below the CCC over the time period but long enough to allow some excursions above the CCC without detrimental effects on the aquatic community. From extensive chronic toxicity tests on single parameters as well as on whole effluents the U.S. EPA concluded that after four days impacts on aquatic test organisms began to occur. The maximum period in which the exposure period should not exceed the CCC was then set at 4 days. The CCC duration may be altered to more accurately reflect the concentration variations within the stream and effluent. If, for example, low variability of concentrations in receiving waters can be demonstrated then longer averaging periods can be specified.

The frequency at which an exceedance may occur is determined after examining the severity of the expected biological impact. An aquatic community which is not accustomed to criteria exceedances can withstand an exceedance better than a community which is constantly being subjected to toxicants at concentrations exceeding criteria. From biological recovery studies it was found that when previously unstressed systems were subjected to small events, the recovery time ranged from a few months to a couple of years for complete recovery (Larimore et al, 1959; Berra and Gunning, 1970; Frey, 1973, 1974; Schott, 1980, 1981, 1982, 1983; Collier, 1981; Carlson, 1984). For unstressed systems it was sufficient to set the frequency at one event occurring every three years. For systems which were under stress from major spills, large areas of impact relative to the size of the water body or long time periods of exposure, the recommended frequency should then be reduced to once every four or more years. Although a community may be able to recover from a major stress in less than three years, the community which is severely stressed every few years would be in constant state of recovery and would not be able to reach its full potential, in terms of abundances and diversity of species. Also, a community which is recovering from a major stress is similar to a very young community and is more vulnerable to repeat impacts. With subsequent stresses the community takes longer to fully recover. A longer return frequency should also be considered if there is a locally important aquatic species present which may be affected by the expected impact.

In addition to the frequency of spills that may occur, impacts may be caused by normal variations in effluent composition, concentrations and dilution flow. The occurrence of low stream flow and high effluent concentration can be predicted and, therefore, modelled. The number of effluent discharges into a particular stream must also be taken into account. If one discharge exceeds the criteria because of low flow then the other discharges are likely to also exceed the criteria. For one discharge the exceedance may seem to be a minor stress but altogether the exceedances may add up to a major stress. When using steady state models, the U.S. EPA recommends the use of 1Q5 and 7Q5 as CMC and CCC design flows for unstressed systems, and 1Q10 and 7Q10 for stressed systems. For the biologically based low flow model the one hour average should not exceed the CMC more than once every three years on the average and the four day average concentration should not exceed the CCC more than once every three years on the average.

3.3 Calculation of Biologically-Based Low Flow

3.3.1 Computational Procedure

The two-number water quality criteria are in an intensity-duration-frequency format. The intensity corresponds to the criteria concentrations, the duration as the averaging periods of flow, and the frequency as the allowed number of excursions occurring within the period of record.

The averaging periods are one hour for the Q_{CMC} and four days for the Q_{CCC}. Unfortunately, most flow records that are available generally consist of one-day average flows, and as a result, the calculation of the CMC design flows must be carried out based on one-day averages, rather than one-hour averages. This should not introduce significant error into the results since naturally occurring low flows of receiving streams are usually very similar from one hour to the next.

The biologically-based design flow computational procedure consists of five parts, and follows an iterative convergence procedure. The biological low flow is emperically derived and represents an actual observed flow. Essentially the five steps may be summarized as follows:

1) Calculation of the allowed number of excursions based on design criteria
2) Calculation of the X-day running averages of streamflow
3) Determination of the number of excursions of a specified flow in a set of running averages
4) Initiation of iterative computational procedure by defining initial limits of design flow and the initial seed trial flow
5) Iterative convergence of computations to the biologically-based design flow

A more detailed explanation of the Biologically-based Design Flow computational procedure is provided in Appendix C.

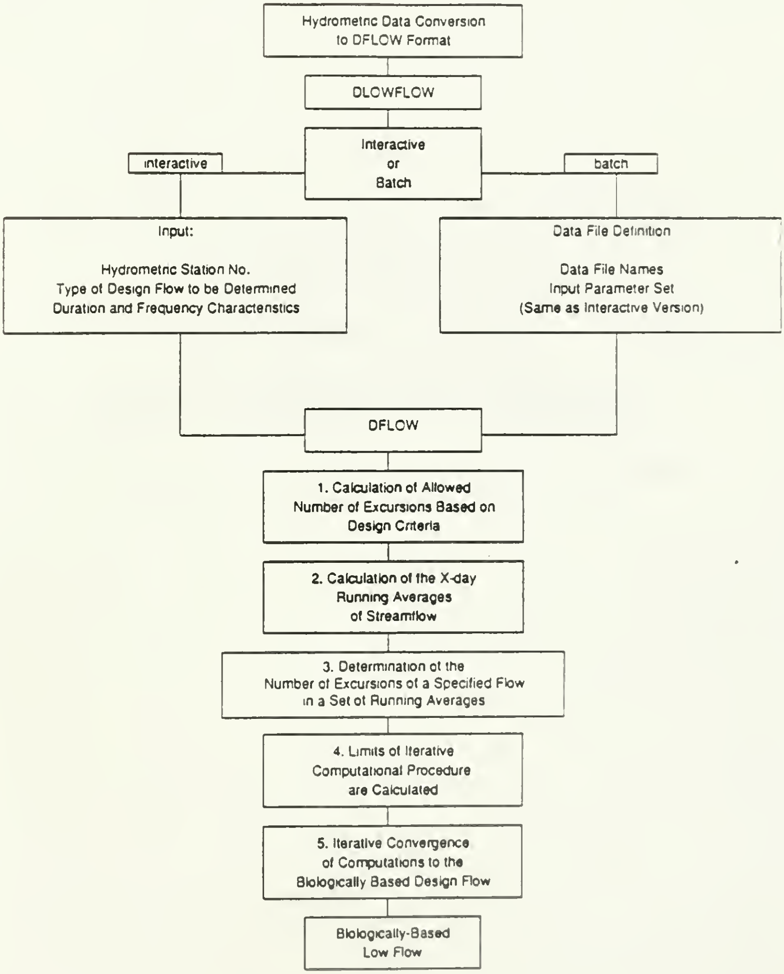
The CMC and CCC concentrations are applied to flow periods which are determined based on the following biological criteria:

1) frequency of occurrence of once in three years on average
2) design flows should not be unnecessarily influenced by droughts which occur over long durations (i.e. the maximum number of exceedances of the design flow is limited for each period of 120 days - although droughts do severely stress aquatic ecosystems due to low flows and high concentrations, many ecosystems can recover within a period of 15 years. As a result, the maximum number of exceedances which can occur over a drought period is 5 (which corresponds to an average of one occurring every three years).

3.3.2 DFLOW Computer Program

A computer model entitled DFLOW has been acquired from the U.S. EPA and modified by Cumming Cockburn Limited. The modified model (renamed DLOWFLOW) permits interactive and batch operations to determine biologically and hydrologically-based low flows for hydrometric data collected on Ontario rivers. Details of the computer program and input file structure are provided in Appendix D.

Figure 3.1 is a flow chart showing the computational procedure used in the computer model for identifying periods where observed flows exceed the biologically defined low flows. It is important to note that the method is emperical, because computations are made using the actual flow record itself. It must be emphasized, therefore, that a statistical distribution is not used to describe the flow record.



Cumming Cockburn Limited
Consulting Engineers and Planners

DFLOW Flow-chart

Figure 3.1

4.0 DEVELOPMENT OF A BIOLOGICALLY-BASED LOW FLOW MODEL FOR ONTARIO

4.0 DEVELOPMENT OF A BIOLOGICALLY-BASED LOW FLOW MODEL FOR ONTARIO

4.1 General

The biologically-based low flow model was developed to use the U.S. EPA's two number system of aquatic water quality criteria (WQC) to calculate flows for wasteload allocation. The current Ontario Provincial Water Quality Objectives identify pollutant concentration values which must not be exceeded at any time for the protection of aquatic life. This represents a fundamental difference to the U.S. methodology, which identifies an acceptable magnitude, duration and frequency of pollutant concentrations that can occur, yet will still permit a resilient aquatic biota in the river system.

One of the goals of this study is to identify appropriate duration and frequency periods such that aquatic biota in Ontario waters can retain their resiliency. In order to develop a duration and frequency format for Ontario rivers to be incorporated into the biologically defined low flow model, one representative parameter was initially considered. The pollutant selected was ammonia since there was a substantial existing body of data on its occurrence and toxicity. However, during evaluation of the biologically defined model, it became apparent that the performance of the model was independent of a specific pollutant(s).

The following section discusses acute and chronic toxicity with respect to the impact on biota resiliency. References and conclusions regarding the effects of ammonia on aquatic biota are based on the literature review detailed in Appendix I.

4.2 Acute and Chronic Toxicity and Their Relationship with Biologically Based Low Flows

The biologically-based low flow model incorporates two important functions from the EPA's two number water quality objective, namely; the duration of adverse exposure and frequency with which exposures exceed the criteria. The frequency of exposure can be chosen with best judgement of how often a population can be reduced without affecting its resiliency. The duration is a set period of time over which average concentrations or flow conditions cannot be exceeded.

Water quality objectives specify how much of a specific pollutant is permitted in the surface waters of the Province. The concentrations for protection of chronic effects and acute effects are determined according to toxicity tests using aquatic organisms.

Toxicity tests measure concentrations of chemicals, singly or as whole effluents, that cause lethal or chronic effects over a specified testing period. An acute toxicity test measures the response of a test organism observed during a short period of time, usually 96 hours or less. If the observed effect is mortality then one can determine the concentration at which 50% of the test organisms are killed (LC50).

Chronic toxicity tests measure the response of a test organism over a longer period of time. The period of time is relative to the lifespan of the organism being tested. A chronic effect may be lethality, reduced reproduction, morphological or physiological changes.

Toxicity criteria are expressed, therefore, as two concentrations so that effluent criteria can more accurately consider toxicological factors. The lower concentration is called the Criterion Continuous Concentration (CCC) and the higher concentration is called the Criterion Maximum Concentration (CMC). Chronic effect concentration (CCC) can be exceeded for a relatively short period of time with no adverse effect so long as the CMC is not exceeded.

The period of time over which measurement of the pollutant within the water body may be averaged for comparison with the specified magnitude criteria is referred to as the duration component. The duration is determined according to how long the exposure concentration can be above the criterion continuous concentration without affecting either survival in the acute toxicity tests or behaviour, growth and/or reproduction in chronic toxicity tests.

The frequency of exceedances of the criteria without unacceptably affecting the community is based on the aquatic communities present within the water body and their ability to recover from exceedances.

In determining water quality criteria the use of various species are recommended as different species exhibit different sensitivities. A range of sensitivities for various species is then assessed. As a result, the development of water quality objectives is based more on the identification of the most sensitive exposure than the most sensitive species. In developing water quality criteria, the Ontario MOE recommends the use of at least 3 different fish species including at least one coldwater species and one warm-water species, at least two different invertebrate species, one of which must be a crustacean and at least one algal or aquatic plant species in toxicological testing. It is not necessary to use indigenous species since the use of the most sensitive test species will likely exhibit a greater sensitivity to the chemical(s). As long as the concentration at which there is no effect to the test species is not exceeded then the indigenous biota will be protected.

The duration for acute effects has been recommended as a one hour averaging period regardless of the parameter in question. For use in the biologically-based model a duration of 1 day will be used since extended flow records are typically available in only one day average flows. In addition, routine water quality data is available as one sample per day for a specific day. The concentrations of ammonia in a water body can vary as a result of variations in loadings (sources) and stream flow. Aquatic organisms would then experience fluctuating exposures rather than a constant, steady exposure.

The question is then whether the organisms are more sensitive to fluctuating concentrations than constant concentrations. In the case of ammonia, the acute response of some fish to ammonia can be very rapid. In studies using green sunfish and rainbow trout, 3 hour LC50's were reported to be 0 to 50% higher than 96 hour LC50's (McCormick et al, 1984; Ball, 1967). In both cases delayed mortalities were not considered. Delayed mortalities would result in a reduction in the duration of exposure. The duration period must be defined appropriately such that the concentration of a pollutant is maintained at or below the CMC for most of the specified time period. If the averaging period is too long, significant excursions over the CMC could occur for an appreciable fraction of the averaging period, which could result in mortality. For example, in the case of ammonia, it is possible that an averaging period of 3 hours would allow for concentrations of 1 to 2 hours duration to exceed the CMC resulting in mortalities. The effects of simple exposures of shorter duration are unknown (EPA 1985). It is, therefore, recommended that the criteria based on acute effects cannot be averaged over any appreciable period of time without seriously impacting the community present.

Studies on acclimation and fluctuating ammonia concentrations also support the use of very short averaging periods for the QCMC. Thurston et al (1981a) found rainbow trout exposed to fluctuating ammonia concentrations were slightly less tolerant than when exposed to constant concentrations when based on the average concentration. Brown et al (1969) found that the more frequent the fluctuations in concentration, the less tolerant rainbow trout were. This suggests that even a one hour average may be too long a duration for averaging if there is the possibility for excursions to occur above the average within the hour.

The EPA (1985) recommends that the one hour average is not applicable to situations where concentrations exceed 1.5 times the average within the one hour period. The 1.5 factor was based on such an excursion being acceptable based on the fluctuating exposure studies mentioned above, with no evidence that greater excursions are tolerable.

Unfortunately, most archived hydrometric data available in the Province are in daily averages. The above research indicates that the CMC should be applied using a 1 hour duration period. It may appear, as a result, that inadequate data are available for defining the Q_{CMC}. Strictly speaking this is the case, however, if one considers the nature of low flows in the Province, only very minor variations occur in flows occurring during low flow sequences. As a result, the inherent error in using daily flow averages to define the Q_{CMC} is likely insignificant.

The duration for chronic effects is determined from chronic toxicity tests for each parameter. The intent of a short duration (i.e. 4 day average) as opposed to a longer period (i.e. 30 day average), which is more reflective of the duration of tests summarized in Appendix E (i), is to prevent the occurrence of concentrations that would substantially exceed the criterion concentration for a substantial fraction of the longer period. A longer period though may be considered if limited variability in the pollutant concentration in the effluents and the background water body can be demonstrated. For the Ontario rivers under consideration, the variability of un-ionized ammonia, for example, was significantly higher within a river than between river systems (see Appendix G). As high variability in the un-ionized ammonia data set was present in the rivers, a longer averaging period than 4 days could not be recommended.

Studies on chronic effects also support the use of a short averaging period for the CCC. Rice and Bailey (1980) studied the effects of prolonged exposure (up to 61 days) to ammonia of pink salmon early life stages. They found that adverse effects on growth increased with increase in exposure. Reichenbach-Klinke (1967) found that the growth of rainbow trout fry was inhibited and their resistance to disease was lessened when exposed to low concentrations of un-ionized ammonia for one week periods. For cold water species exposure to very low concentrations of un-ionized ammonia for periods ranging from 8 weeks to under 30 days resulted in chronic effects including macroscopic malformations, hyperplasia and retardation in early growth and development (Samylin, 1969; Fromm, 1970; Burkhalter and Kaya, 1977; Thurston et al, 1978).

It appears that fish will avoid ammonia concentrations which are fatal (Summerfelt and Lewis, 1967) but will not avoid chronic levels of ammonia (Westlake and Lubinski, 1976). Exposure to chronic concentrations of ammonia for even periods of four days resulted in measurable effects (Jude, 1973; Westlake and Lubinski, 1976). Long term effects were not noticed for the short duration periods. To protect against chronic effects it is recommended that the duration for the CCC be a four day averaging period. Where large diurnal fluctuations in un-ionized ammonia concentration can be demonstrated it is recommended that the maximum daily concentration be applied in waste load allocation when used in calculation of the 4 day averaging period as chronic effects may be better correlated to maximum daily concentrations rather than mean concentrations (Soderberg et al, 1983).

A detailed description of the biological considerations with respect to ammonia and its toxicity is provided in Appendix I. A typical waste load allocation may, therefore, consist of the following:

Where available, PWQO's or PWQG's would be used as allowable maximum concentrations to apply to the biologically designed low flows. In the absence of provincial water quality criteria, published toxicity values for single chemicals would be used. For complex industrial effluents, the toxicity must be measured on a case-by-case basis, and lethality expressed as a percent (%) volume of the total sample. Data required after development of the biologically designed low flow model would consist of effluent concentrations so exceedances of provincial water objectives could be determined. An example of waste load allocation using the two methodologies is provided in Appendix J.

4.3 General Conclusions on Design Flow Durations and Frequencies for the Province of Ontario

The biological low flow model can be applied to a river system, independent of pollutant considerations. Since effluent toxicity or concentration is applied to the biologically defined low flow as a base concentration in waste load allocation, the aquatic system will retain resiliency providing river flow characteristics satisfy the frequency and duration required by the biological low flow model.

To date little or no field data are available regarding chronic toxicity following spills (D. Dodge, MNR, Pers. Comm.). The length of time required for aquatic life to recover from chemical exposure is highly site specific. The rate of recovery is dependent on the species present, their abundance, length of exposure, maximum exposure concentrations, number of refuge areas, etc. Until additional research and data are collected with regard to these factors, the research carried out in this study indicates that the duration and frequency time periods specified by the EPA are the most appropriate for river systems in Ontario.

Therefore, based on the literature review of the toxicity of ammonia, and its general applicability to other pollutants, the findings provide support for use of EPA's definitions of duration and frequency (4 day, 3 year for chronic design flow, Q_{CCC}; 1 day, 3 year for acute design flow, Q_{CMC}).

5.0 EVALUATION OF BIOLOGICALLY- AND HYDROLOGICALLY- DEFINED LOW FLOWS FOR RIVERS IN ONTARIO

5.0 APPLICATION OF BIOLOGICALLY-BASED LOW FLOW METHOD TO RIVERS IN ONTARIO

5.1 General

This section summarizes the results of applying the biological low flow methodology to hydrometric data collected in the Province of Ontario. Q_{CMC} and Q_{CCC} flows are calculated and compared to hydrologically defined low flows. Conclusions are drawn regarding the merit of the existing $7Q_{20}$ hydrologically defined design low flow with respect to the biological considerations and incorporating the general concepts of reliability, resiliency and vulnerability of rivers to excursions from water quality objectives.

5.2 Data Set

The data set initially considered in the study consisted of hydrometric data from 39 hydrometric stations operated by Water Survey of Canada and water quality data collected at or near the hydrometeric stations by MOE. For evaluation of the biologically-based low flow method, only the hydrometric data was required. Some of the stations in the original data set were found to have less than 10 years of hydrometric information available, and hence, were considered inappropriate for establishing conclusive low flow characteristics. As a result, the acute and chronic design flows were determined for the 30 hydrometric stations listed in Table 5.1.

Streamflow data for the 30 hydrometric stations were assembled from the archives of the Water Survey of Canada. Daily average streamflow values were used in the analysis for determination of both the chronic and acute design flows. Details regarding characteristics of the hydrometric stations are provided in Appendix H.

Table 5.1 Hydrometric Stations Used in the Study

River Name	Hydrometric Station No.	Analysis Period
1 Neebing River	02AB008	1954 - 1986
2 Black River	02BB002	1968 - 1986
3 Magpie River	02BD003	1953 - 1986
4 Batchawana River	02BF001	1968 - 1986
5 Serpent River @ Hwy 17	02CD001	1967 - 1986
6 Serpent River	02CD006	1973 - 1986
7 Whitson River	02CF007	1961 - 1986
8 Duchesnay River	02DD008	1957 - 1982
9 Holland River	02EC009	1966 - 1986
10 Beaverton River	02EC011	1967 - 1986
11 Coldwater River	02ED007	1966 - 1986
12 Sauble River	02FA001	1958 - 1986
13 Saugeen River	02FC002	1915 - 1986
14 Nith River	02GA018	1951 - 1986
15 Fairchild Creek	02GB007	1965 - 1986
16 Big Otter Creek	02GC010	1961 - 1986
17 Catfish Creek	02GC018	1965 - 1986
18 Grindstone Creek	02HB012	1966 - 1986
19 East Humber River	02HC009	1954 - 1986
20 Highland Creek	02HC013	1958 - 1986
21 Lynde Creek	02HC018	1961 - 1986
22 Don River @ Bayview Exit	02HC024	1963 - 1986
23 Humber River	02HC025	1963 - 1986
24 Etobicoke Creek	02HC030	1967 - 1986
25 Mimico Creek	02HC033	1966 - 1986
26 Wilmot Creek	02HD009	1966 - 1986
27 Shelter Valley Brook	02HD010	1966 - 1986
28 Jackson Creek	02HJ001	1963 - 1986
29 Skootamatta River	02HL004	1956 - 1986
30 Moira River @ Hwy. 7	02HL005	1966 - 1986

5.3 Evaluation and Comparison of Biologically and Hydrologically-Based Design Low Flows

5.3.1 Evaluation Procedure

Recent studies carried out by MOE (Logan, 1986, 1988) focussed on evaluating the performance of six rivers in the Province of Ontario with respect to satisfying water quality objectives. The study used an evaluation process which considered probability concepts of reliability, resiliency and vulnerability. Performance was measured by evaluating the rivers capability to maintain water quality conditions to the requirements of provincial water quality objectives, the ability of the tributaries to recover from failure; and the significance of the consequence of failures. These concepts have been applied in a general sense in evaluating and comparing the two low flow design methodologies.

Section 4.0 discussed the biological considerations inherent in the selection of a flow duration and frequency for calculation of design low flows. Therefore, implicit in the biologically based low flow computational methodology is the concept of resiliency, or the ability of the river system to recover from an excursion from water quality objectives. In terms of evaluating the hydrological flows with respect to biological considerations, therefore, it is necessary not only to compare magnitudes of flow but also the number of excursions which might be expected using the design flow. These factors were evaluated empirically using the sample data sets.

The following three evaluation criteria were used in assessing the performance of the existing definition of low flow ($7Q_{20}$) and other hydrologically defined low flows with respect to biological considerations:

1) the ratio of the number of excursions which would result if the hydrologic flow was used as the design criteria versusthe number of excursions which would occur using the biologically defined flow as the design criteria.

2) the (absolute) difference in magnitude of design low flows using the two design low flow methodologies.

3) the (absolute) relative difference in magnitude of design low flows using the two design low flow methodologies.

A measure of the reliability of a hydrologically defined low flow which appropriately reflects biological considerations is a comparison which would result in a similar number of excursions as that occurring using the biologically based methodology. In addition, the average flow magnitudes should be similar.

Vulnerability, as defined by Logan, is a measure involving intensity and duration of exceedance of water quality objectives. This is used to assess the severity of a failure in a system. In the context of this study, the vulnerability of a river system was indexed in terms of the sensitivity of the number of excursions from water quality objectives to the biologically based design flow (since intensity and duration are implicitly considered in the definition of biologically based low flows). In other words, vulnerability was assessed relative to the increased number of excursions as the hydrologic design low flow deviates from the biologically defined design low flow.

5.3.2 Hydrologically Defined Design Low Flows

The hydrologically defined design low flows were assembled from values published in a recent report (CCL, 1989). Extreme values were calculated using the Gumbel III distribution. Design flows were determined for all combinations of averaging periods of 1, 3, 7, 15 and 30 days and frequencies of 2, 5, 10 and 20 years. The hydrologically-based design flows for each hydrometric station are summarized in Appendix H.

5.3.3 Biologically Defined Design Low Flows

The biologically defined low flows were determined using durations and frequencies appropriate for Ontario (as explained in Section 4.0). The 4 day-3 year chronic design flows (Q_{CCC}) and the 1 day-3 year acute design flows (Q_{CMC}) were determined for the 30 hydrometric stations using the DFLOW program. The biologically-based design flows for each hydrometric station are also summarized in Appendix H.

5.3.4 Results

The evaluation criteria discussed in Section 5.3.1 was applied to the biologically and hydrologically defined low flows at each of the hydrometric stations. The results are summarized in tables in Appendix H for each of the hydrometric stations. The values of the parameters determined in the evaluation procedure varied for different hydrologic flows for each station and varied between hydrometric stations. In order to derive specific conclusions from the overall analysis procedure, average values for each of the parameters, for each of the hydrologic design flows were determined, and are summarized in Table 5.2.

Based on the results in Table 5.2, the current hydrologic design low flow ($7Q_{20}$) is the most similar to the CCC design flow in terms of flow magnitudes and the number of excursions. Therefore, with respect to reliability, it can be concluded that the current MOE design low flow is the most appropriate to use for assessing chronic design flow conditions.

With respect to the acute design flows, should the MOE consider adopting a two-number criteria, the optimum design low flow would

Table 5.2 Summary of Results **

Hydrologic Design Flow Parameters	(6)/(2)	(5)-(1) (m^3/s)	(5)-(1)/(5)	(7)/(4)	(5)-(3) (m^3/s)	(5)-(3)/(5)
1-Q- 2	6.59	0.436	0.44	10.40	0.478	0.51
1-Q- 5	2.16	0.147	0.20	3.50	0.182	0.29
1-Q-10	1.04	0.079	0.17	1.95	0.071	0.15
1-Q-20	0.38	0.082	0.40	0.93	0.058	0.20
3-Q- 2	7.79	0.476	0.47	12.02	0.519	0.54
3-Q- 5	2.63	0.182	0.24	4.39	0.224	0.34
3-Q-10	1.43	0.066	0.11	2.57	0.096	0.19
3-Q-20	0.61	0.047	0.21	1.37	0.035	0.11
7-Q- 2	9.52	0.522	0.50	14.03	0.564	0.57
7-Q- 5	3.41	0.221	0.30	5.75	0.264	0.39
7-Q-10	1.86	0.091	0.15	3.39	0.133	0.26
7-Q-20	1.01	0.030	0.10	2.16	0.057	0.16
15-Q- 2	12.26	0.591	0.54	17.54	0.634	0.60
15-Q- 5	4.87	0.275	0.37	8.08	0.317	0.46
15-Q-10	2.78	0.136	0.25	5.09	0.179	0.35
15-Q-20	1.79	0.048	0.14	3.50	0.086	0.25
30-Q- 2	17.82	0.706	0.61	24.51	0.748	0.66
30-Q- 5	8.14	0.352	0.46	12.29	0.394	0.53
30-Q-10	4.84	0.199	0.35	8.00	0.241	0.44
30-Q-20	3.13	0.090	0.25	5.52	0.133	0.35

(1) = CCC Design Flow
(2) = Number of Excursions from Chronic Design Flow using (1)
(3) = CMC Design Flow
(4) = Number of Excursions from Acute Design Flow using (3)
(5) = Hydrologic Design Flow
(6) = Number of Excursions Using (5) as CCC Design Flow
(7) = Number of Excursions Using (5) as CMC Design Flow

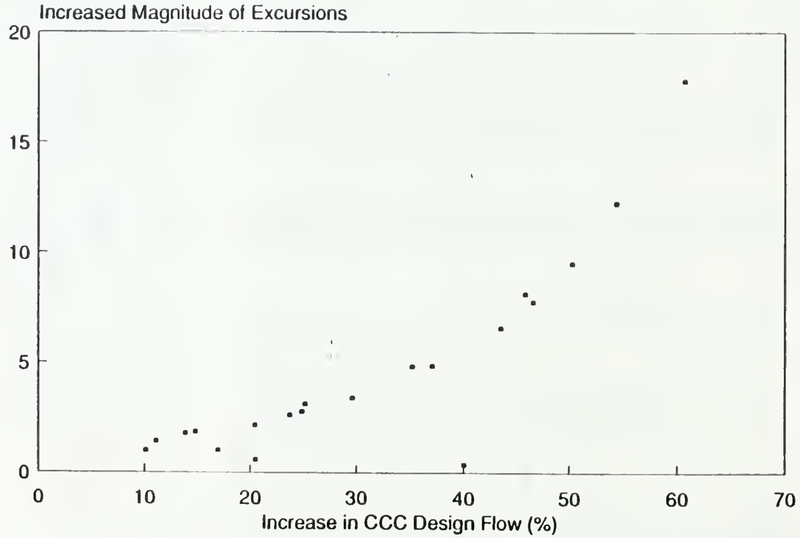
** average of analysis parameters determined for
30 hydrometric stations summarized in Appendix H

be either the $1Q_{20}$ or the $3Q_{20}$. In terms of an appropriate number of excursions, on average, the $1Q_{20}$ yields the closest number to the biological CMC design flow. However, with respect to flow magnitudes, the $3Q_{20}$, on average, is the closest to the Q_{CMC}. Results of a similar investigation by the U.S. EPA (1986) recommended the use of the $7Q_{10}$ flow for the Q_{CCC} and the use of the $1Q_{10}$ for the Q_{CMC}.

Figures 5.1a and 5.1b illustrate the concept of vulnerability with respect to the number of excursions which could occur if the design low flows were to deviate from their appropriate biologically defined values. The figures illustrate, for example, that if the design low flows were to deviate from the biological value by 25%, an excursion could be expected to occur once a year, on average, rather than the desired frequency of once every three years. Thus, a small difference in value of the design low flow could have a significant impact on the resiliency of the river system. Since the hydrologic $7Q_{20}$ is nearly equivalent in magnitude on average to the Q_{CCC}, the continued use of $7Q_{20}$ would maintain a high resiliency and a low vulnerability during low flow conditions for river systems in Ontario.

The findings of this study are generally consistent with the findings of a recent investigation (Logan, 1986) which concluded that the $7Q_{20}$ design low flow provides high reliability, moderate resiliency and negligible vulnerability.

Vulnerability of River Systems
(Measured in terms of Excursions)



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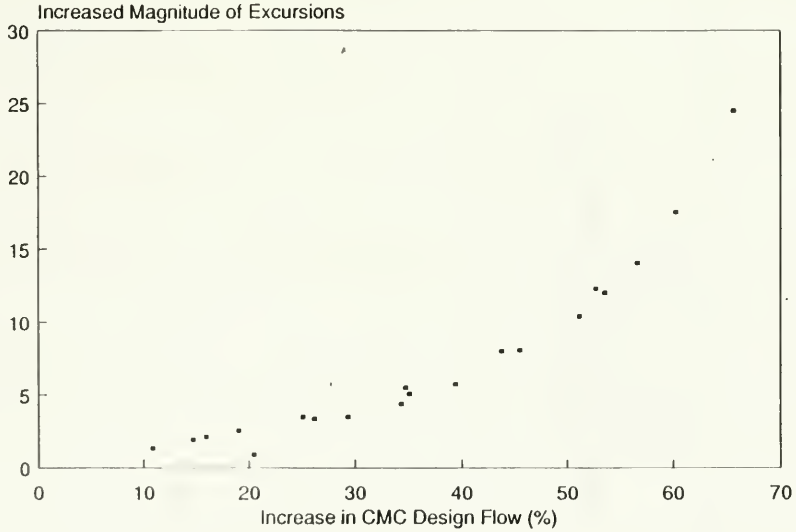
Vulnerability of River Systems

Vulnerability of River Systems
(Measured in terms of Excursions)



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Vulnerability of River Systems

Figure 5.1b

6.0 CONCLUSIONS AND RECOMMENDATIONS

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6.1 Conclusions

Based on the results of this investigation of the biologically-based low flow methodology, the following conclusions can be made:

1) The biological low flow model can be applied to a river system independent of pollutant considerations.
2) Based on available toxicity data, the U.S. EPA's definition of duration and frequencies are the most appropriate for Ontario (4 day - 3 year for chronic design flow; 1 day - 3 year for acute design flow)
3) The $7Q_{20}$ hydrologically defined low flow is similar to the chronic design flow in terms of flow magnitudes and the expected number of excursions from water quality objectives.
4) The $7Q_{20}$ low flow provides high reliability and resiliency, and low vulnerability based on comparison to the biological low flow method
5) the $3Q_{20}$ and $1Q_{20}$ are similar to the acute design flow.

6.2 Recommendations

The following recommendations are made:

1) The MOE should continue use of the $7Q_{20}$ as the design low flow for the Province of Ontario
2) Additional research studies should be undertaken to measure the short and long term effects of chronic and acute toxicity following spills.
3) Consideration should be given to evaluating the practicality and/or improvement in wasteload allocation by incorporating probability analysis through dynamic modelling. In so doing, receiving water concentrations will be more appropri-

ately identified by incorporating realistic flow and pollutant loading combinations, than by application of the single worst case based on a combination of critical conditions.

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APPENDIX A

GLOSSARY OF TERMS

Glossary of Terms

Acclimation

Steady state compensatory adjustments by an organism to the alteration of environmental conditions. Adjustments can be behavioral or physiological/biochemical.

Acute

Having a sudden onset, lasting a short time. Of a stimulus, severe enough to induce a response rapidly. Can be used to define either the exposure or the response to an exposure (effect). The duration of an acute aquatic toxicity test is generally 4 d or less and mortality is the response measured.

Chronic

Involving a stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the aquatic species. Can be used to define either the exposure or the response to an exposure (effect). The chronic aquatic toxicity test is used to study the effects of continuous, long-term exposure of a chemical or other potentially toxic material on aquatic organisms.

Concentration

The quantifiable amount of chemical in the surrounding water, food or sediment.

Criteria (water quality)

An estimate of the concentration of a chemical or other constituent in water which if not exceeded, will protect an organism, an organism community, or a prescribed water use or quality with an adequate degree of safety.

Criteria continuous concentration

The EPA national water quality criteria recommendation for the highest instream concentration of a toxicant or an effluent to which organisms can be exposed indefinitely without causing an unacceptable affect.

Criteria maximum concentration

The EPA national water quality recommendation for the highest instream concentration of a toxicant or an effluent to which organisms can be exposed for a brief period of time without causing mortality.

Delayed effects

Effects or responses that occur some time after exposure.

Duration

The period of time over which the instream concentration is averaged for comparison with criteria concentrations. The duration of exposure considers the amount of time aquatic organisms will be exposed to toxicants. This specification limits the duration of a concentration above the criteria.

Effluent

A complex waste material (e.g., liquid industrial discharge or sewage) which may be discharged into the environment.

Frequency

An amount of time criteria concentrations can be exceeded during a given period of time without unacceptably affecting the community.

Incipient LC50

The concentration of a chemical which is lethal to 50% of the test organisms as a result of exposure for periods sufficiently long that acute lethal action has essentially ceased.

Lethal

Causing death by direct action.

Lowest observed effect concentration (LOEC)

The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.

Magnitude

The amount of a pollutant, or pollutant parameter such as toxicity, expressed as a concentration or toxic unit, which is allowed within a water body.

No observed effect concentration (NOEC)

The highest concentration of a material in a toxicity test that has no statistically significant adverse effect on the exposed population of test organisms as compared with the controls.

Standard (water quality)

The limiting concentration which is permitted in an effluent or waterway. Standards are established for regulatory purposes and are determined from a judgement of the criteria involved.

Toxic unit

The strength of a chemical expressed as a fraction or proportion of its lethal threshold concentration.

$$\text{Toxic unit} = \frac{\text{actual concentration of chemical in solution}}{\text{lethal threshold concentration}}$$

Toxicity

The inherent potential or capacity of a material to cause effects in a living organism.

APPENDIX B

CALCULATION OF HYDROLOGICALLY DEFINED LOW FLOWS

APPENDIX B
EXTREME VALUE ANALYSIS

Introduction

Statistical distributions allow estimates of probability of exceedance of events to be made by analytical techniques. Various methods are available, and a good discussion is given by McMahon and Mein (1986).

At a gauged location, average low flows can be determined for selected durations of time for each year of record. For example, the corresponding minimum average consecutive 15-day low flow can be determined for each annual record. The series of 15-day average annual low flows can then be ranked lowest to highest and an extreme value analysis undertaken using a theoretical distribution.

The Gumbel Type III Distribution

This is a variation of Fisher and Tippett's third asymnptotic distribution of extreme values and is sometimes referred to as the Weibull distribution. In view of his many contributions it is often referrred to in hydrology as the Gumbell II. The probability density function is:

$$\phi(x) = \frac{a}{u - e} \left\{ \frac{x - e}{u - e} \right\}^{a-1} \exp \left[- \left\{ \frac{x - e}{u - e} \right\}^{a} \right] \qquad (1)$$

where e is the lower bound parameter
u is the characteristic drought
and a is the shape parameter

Various methods are available for determining the distribution parameters for a particular data set. See Condie and Cheng (1983) and Pilon et al (1985) for example.

The Probability Function

The density function is integrable and gives the distribution function

$$F\ (x) = 1 - \exp \left[- \left\{ \frac{x - e}{u - e} \right\}^{a} \right] \tag{2}$$

which gives the probability of non-exceedance of x.
Since it is more common to require x for a given probability of non-exceedance, a simple re-arrangement gives

$$x = e + (u - e) \left\{ - \ln \left[1 - F(x) \right]^{1/a} \right\} \tag{3}$$

There are occasions when the sample series of low flows can have a large negative coefficient of skewness, and since the Gumbel Type III distribution cannot have a skewness of less than -1.14, then the distribution cannot be fitted.

There are insuffucient natural samples available with such low skewness to make a firm choice of an alternative treatment, but from the few available, it was found that the negatively skewed three-parameter lognormal distribution provided an acceptable alternative.

If $y = \ln (a-x)$ is normally distributed, then the probability density function of x is given by

$$\phi(x) = \frac{1}{(x-a)\sigma\sqrt{2\Pi}} \quad \exp - \left\{ -\frac{1}{2\sigma^2} \left[\ln\ (x-a)\ - m \right]^2 \right. \tag{4}$$

where m and σ are respectively the mean and standard deviation of the series ln (x-a) and a is an lower boundary parameter. This form of the distribution can only have negative skewness.

Taking moments, re-arranging and replacing them by their sample estimates gives:

$$k^3 + 3k - g_1 = 0 \qquad (36a) \quad (5)$$

and after solving for k

$$= x - s/k \qquad (37a) \quad (6)$$

$$m = \ln(-s/k) - 1/2\ln(k^2+1) \qquad (38a) \quad (7)$$

$$\hat{o}^2 = \ln(k2+1) \qquad (39a) \quad (8)$$

Thus, the distribution is completely defined and the T-year low flows can be computed from:

$$Q_T = \quad - \exp(\hat{m}\ \hat{o}t) \qquad (9)$$

Source: Condie, R., L. C. Cheng
"Low Flow Frequency Analysis - Program LOFLOW",
Water Resources Branch, Inland Waters Directorate
Environment Canada, Ottawa, 1987

APPENDIX C

CALCULATION OF BIOLOGICALLY DEFINED LOW FLOWS

APPENDIX C

CALCULATION OF BIOLOGICALLY DEFINED LOW FLOWS

The following description of the computational procedure of the biological low flow method is based on U.S. EPA (1986).

The biologically-based design flow calculation method is an iterative conveyance procedure consisting of five parts. In Part I, Z (the allowed number of excursions) is calculated. In Part II, the set of X-day running averages is calculated from the record of daily flows. Because the ambient (instream) concentration of a pollutant can be considered to be inversely proportional to streamflow, the appropriate "running averages" of streamflow are actually "running harmonic means". (The harmonic mean of a set of numbers is the reciprocal of the arithmetic mean of the reciprocals of the numbers.) Thus, "X-day running averages" should be calculated as $X\Sigma(1/F)$, not as $(\Sigma F)/X$, where F is the flow for an individual day. Throughout this Appendix, the term "running average" will mean "running harmonic mean".

Part III describes the calculation of N (the total number of excursions of a specified flow in the flow record). The calculations described in Part III will be performed for a number of different flows that are specified in Parts IV and V. In Part IV, initial lower and upper limits on the design flow are calculated, the number of excursions at each limit are calculated using Part III, and an initial trial flow is calculated by interpolation between the lower and upper limits. In Part V, successive iterations are performed using the method of false position (Carnahan et al (1969) to calculate the design flow as the highest flow that results in no more than the number of allowed excursions calculated in Part I.

Part I. Calculation of allowed number of excursions.

I-1. Calculate $Z = D/[(Y)\ (365.25\ \text{days/year})]$

where D = the number of days in the flow record

Y = the average number of years specified in the frequency; and

Z = the allowed number of excursions.

PART II. Calculation of X-day running averages (i.e. x-day running harmonic means)

II.1. Where X = the specified duration (in days) of the averaging period, calculate the set of X-day running averages for the entire flow record (i.e. calculate an X-day average staring with day 1, day 2, day 3, etc.) Each average will have X-1 days in common with the next average, and the number of X-day averages calculated from the flow record will be (D+1-X).

PART III. Determination of the number of excursions of a specified flow in a set of running averages (i.e. running harmonic means).

III-1. Obtain a specified flow of interest from either Part IV or Part V

III-2. In the set of X-day running averages for the entire flow record, record the date for which the first average is below the specified flow and record the number of consecutive days that are part of at least one or more of the X-day averages that are below the specified flow. (Note that whether a day is counted as an excursion day does not depend exclusively on whether the X-day average for that day is below the specified flow of interest. Instead, it depends entirely on whether that day is part of any X-day average that is below the specified flow. Table C-1 provides examples of the counting of excursion days.

Thus the starting date and the duration (in days) of the first excursion period will be recorded. By definition, the minimum duration is X days.

III-3. Determine the starting dates of, and number of days in, each succeeding excursion period in the flow record.

III-4. Identify all of the excursion periods that begin within 120 days after the beginning of the first excursion period. (Although the first excursion period is often the only one in the 130-day period, two or three sometimes occur within the 120 days. Rarely do any excursion periods occur during days 121 to 240.) All of these excursion periods are considered to be in the first low flow period. Add up the total number of excursion days in the first low flow period and divide the sum by X to obtain the number of excursions in the first low flow period. If the number of excursions is calculated to be greater than 5.0, set it equal to 5.0.

III-5. Identify the first excursion period that begins after the end of the first low flow period, and start the beginning of the second 120-day low flow period on the first day of this excursion period. Determine the number of excursion days and excursions in the second low flow period.

III-6. Determine the starting dates of, and the number of excursions in, each succeeding 120-day low flow period.

III-7. Sum the number of excursions in all the low flow periods to determine S = the total number of excursions of the specified flow of interest.

PART IV. Calculation of initial limits of the design flow and initial trial flow.

IV.1. Use L - 0 as the initial lower limit.

IV.2. Use U = the XQY low flow as the initial upper limit.

IV.3. Use $N_L=0$ as the number of excursions (see Part III) of the initial lower limit.

IV.4. Calculate N_U = the number of excursions (see Part III) of the initial upper limit.

IV.5. Calculate T = the initial trial flow as $T + L + \dfrac{(Z-N_L)\ (U-L)}{(N_U - N_L)}$

and repeat steps V-1, V-2, and V-3 as necessary.

TABLE C.1

COUNTING EXCURSION DAYS FOR A SPECIFIED FLOW OF 100 FT^3/SEC USING 4-DAY AVERAGES

Date	Daily Flow	4-Day Avg. Flow	Is the 4-day Average Below 100	Is the date part of any 4-day average that is below 100?	Date of Start of Excursion Period	Number of days in Excursion Period	Date of Start of Low Flow Period	Number of Excursion Days in Low Flow Period	Number of Excursions in Low Flow Period
1	130	112.5	No	No					
2	120	102.5	No	No					
3	110	97.5	Yes	Yes	3	4	3	12	3
4	90	102.5	No	Yes					
5	90	117.5	No	Yes					
6	100	112.5	No	Yes					
7	130	102.5	No	No					
8	150	102.5	No	No					
9	70	87.5	Yes	Yes	9	8			
10	60	90.0	Yes	Yes					
11	130	102.5	No	Yes					
12	90	95.0	Yes	Yes					
13	80	97.5	Yes	Yes					
14	110	127.5	No	Yes					
15	100	225.0	No	Yes					
16	100	>100	No	No					
17	200	>100	No	No					
18	500	>100	No	No					

The daily flows and four-day average flows for days 19 to 200 are all above 100 ft^3/sec.

APPENDIX D

DESCRIPTION OF DFLOW

A Computer Program For Calculating Biologically-Based Low Flows

APPENDIX D

DESCRIPTION OF DFLOW

Cumming Cockburn Limited retained a copy of the U.S. EPA's DFLOW computer program and source code. The computer program has been modified to allow either batch or interactive operations. The following summarizes the input file requirements for both types of operation. Sample input data files are also provided.

Batch Version:

- Files Involved:

1) DLOWFLOW•EXE (Task File)
2) Input File : Hydrometric Data Files
   - Name of these data files consist of the Water Survey Identification Number with '•Bio' as extension
   - Example 02HB012•BIO (W.S. Id. number)
3) PARAM•DAT consists of records of variables summarizing requested options. Refer to D.2 Parameter File Description Sheet for particular input format requirements.

Interactive Version:

- Files Involved:

1) DFLOW•EXE (Task File)
2) Input File : Hydrometric data files (same as above).

D.2 PARAMETER FILE DESCRIPTION SHEET

Line	Field	Variable	Description
1	A7 (17)	Station No.	Water Survey Identification Number
2	I (1)	I	No. of Design Flow to be calculated '1' - CMC '2' - CCC '3' - User Defined
	If I = 1 or I = 2:		
3	I4 (1-4)	Num	Number of Flows for Calculation of Excursions
4	F10-11 (1-10)	Flow	Flow values (cms)
	End-of-Record		
	If I = 3:		
2	I4 (1-4)	K	Type of Design '1' - Biologically Based '2' = Extreme Value xQy
3	I4 (1-4)	M	Number of days in a flow averaging period (1 for CMC, 4 for CCC)
4	F10.0 (1-10)	XMR	Average number of years between excursions (3)
	If K = 1:		
5	F10.0 (1-10)	XME	Maximum number of excursions in a low flow period (5)
6	F10.0 (1-10)	XMI	Maximum number of days in a low flow period (100)
7	I4 (1-4)	J1	Beginning year of flow record (1900)
8	I4 (1-4)	J2	Ending year of flow record (1999)
9	I4 (1-4)	Num	Number of Flows for Calculation of Excursions

Line	Field	Variable	Description
10	F10.0	Flow	Flow values (cms)
	End-of-Record:		
	If K = 2:		
5	I4 (1-4)	J1	Beginning year of flow record (1900)
	I4 (1-4)	J2	Ending year of flow record (1999)
	End-of-Record		

Sample Input Data File PARAM.DAT

```
02FC002
2
  10
5.538
4.019
3.360
2.903
6.066
4.655
4.032
3.594
6.429
5.006
```

Sample Output Listing 02FC002.dat

```
02FC002  1915-1986       23.906  |  02FC002   = Hydrometric Station
2     3.882    21.500            |  1915-1986 = Period of Record
     5.538   114.750             |  23.906    = Theoretical Number of Excursions
     4.019    30.250             |  2         = CCC Indicator
     3.360     6.250             |  3.882     = CCC Flow
     2.903      .000             |  21.500    = Number of Excursions Using CCC
     6.066   162.000             |  5.538     = First Flow to Calc. # of Excurs
     4.655    61.000             |  114.75    = Number of Excursions for Q=5.538
     4.032    30.500             |  4.019     = Second Flow etc.
     3.594    12.250             |
     6.429   189.500             |
     5.006    78.750             |
```

Sample Hydrometric Data File for Station 02FC002 (02FC002.BIO)

```
02FC002
 15  1  1   0.115000E+02
 15  1  2   0.108000E+02
 15  1  3   0.137000E+02
 15  1  4   0.137000E+02
 15  1  5   0.144000E+02
 15  1  6   0.170000E+02
 15  1  7   0.170000E+02
 15  1  8   0.178000E+02
 15  1  9   0.178000E+02
 15  1 10   0.170000E+02
 15  1 11   0.160000E+02
 15  1 12   0.170000E+02
 15  1 13   0.170000E+02
 15  1 14   0.170000E+02
 15  1 15   0.160000E+02
 15  1 16   0.153000E+02
 15  1 17   0.178000E+02
 15  1 18   0.178000E+02
 15  1 19   0.187000E+02
 15  1 20   0.187000E+02
 15  1 21   0.170000E+02
 15  1 22   0.161000E+02
 15  1 23   0.161000E+02
 15  1 24   0.161000E+02
 15  1 25   0.170000E+02
 15  1 26   0.170000E+02
 15  1 27   0.161000E+02
 15  1 28   0.161000E+02
 15  1 29   0.144000E+02
 15  1 30   0.144000E+02
 15  1 31   0.144000E+02
```

APPENDIX E

SUMMARY OF TOXICITY RESEARCH

(i) Chronic Toxicity
(ii) Acute Toxicity

Table (L) SUMMARY OF CHRONIC TOXICITY OF AMMONIA TO FRESHWATER ANIMALS

Species	Test Conditions[1]	pH	Temperature (°C)	D.O. (mg/L)	Unionized Ammonia Chronic Value (mg/L NH_3)2 Concentration[2] (mg/L)	Reference
Cladoceran, *Ceriodaphnia acanthina*	LC	7.0-7.5	24.0-25.0	5.7-6.4	0.304	Mount 1982
Cladoceran, *Daphnia magna*	LC	8.09	22.1	6.9-7.7	0.527	Russo et al. 1985
Cladoceran, *Daphnia magna*	LC	7.63-8.16	17.8-20.8	88-91% saturated	1.2	Reinbold & Pescitelli 1982a
Pink salmon, *Oncorhynchus gorbuscha*	ELS	6.3-6.5	4	-	0.0017	Rice & Bailey 1980
Rainbow trout, *Salmo gairdneri*	ELS	7.4	14.5	>80% saturated	0.016	Calamari et al. 1977 1981
Rainbow trout, *Salmo gairdneri*	LC	7.69-7.72	9.3	7.3-7.6	0.0311	Thurston et al. 1984b
Rainbow trout, *Salmo gairdneri*	ELS	7.4-7.6	10-12	>8	<0.06	Burkhalter & Kaya 1977
Atlantic salmon, *Salmo salar*	ELS	6.7-7.5	13	10	0.01	Samylin 1969
Fathead minnow, *Pimephales promelas*	LC	7.99-8.01	24.0-24.2	6.3-6.5	0.13	Thurston et al. In US EPA (1986)
Fathead minnow, *Pimephales promelas*	ELS	7.63-8.13	22.7-26.3	6.6-7.8	0.22	Swigert & Spacie 1983
White sucker, *Catostomus commersoni*	ELS	8.01-8.65	16.9-20.5	68-74% saturated	0.058	Reinbold & Pescitelli 1982a
Channel catfish, *Ictalurus punctatus*	ELS	7.6-7.8	25.1-25.3	5.1	0.103	Robinette 1976
Channel catfish, *Ictalurus punctatus*	J	8.30-8.44	27.8-28.0	7.4-7.8	<0.25	Colt & Tchobanoglous 1978
Channel catfish, *Ictalurus punctatus*	J	7.53-8.37	24.8-28.4	70-76% saturated	0.283	Reinhold & Pescitelli 1982a
Channel catfish, *Ictalurus punctatus*	ELS	7.34-7.95	23.5-28.0	3.6-6.7	0.18	Swigert & Spacie 1983
Green sunfish, *Lepomis macrochirus*	ELS	7.9	22	7.09	0.33	McCormick et al. 1984
Bluegill, *Lepomis macrochirus*	ELS	7.74	22	7.05	0.0926	Smith et al. 1984
Smallmouth bass, *Micropterus dolomieui*	ELS	6.60-8.68	22.2-22.5	7.68-7.78	0.0437	Broderius et al. 1985

Legend:

1. LC = life cycle
   ELS = early life stage
   J - juvenile

2. Lowest recorded Final Chronic Value.

Table [illegible]) SUMMARY OF ACUTE TOXICITY OF AMMONIA TO FRESHWATER ANIMALS

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Flatworm, *Dendrocoelum lacteum* *(Procotyla fluviatilis)*	S,U	LC50	1.4	8.2	18		Stammer 1953
Tubificid worm, *Tubifex tubifex*	S,U	LC50	2.7	8.2	12		Stammer 1953
Snail, *Physa gyrina*	FT,M	LC50	1.59	8.0-8.2	4.0-5.5	12.3-12.5	West 1985
Snail, *Physa gryina*	FT,M	LC50	1.78	8.0-8.2	12.1-13.3	9.5-10.4	West 1985
	FT,M	LC50	1.71	8.0	24.9	7.1	West 1985
Snail, *Helisoma trivolvis*	FT,M	LC50	2.76	8.2	12.9	9.5	West 1985
Clam, *Musculium transversum*	FT,M	LC50	0.93	8.1-8.6	5.4-20.5	8.6	West 1985
Cladoceran, *Ceriodaphnia acanthina* <2-h	FT,M	LC50	0.770	7.06	24	4.8-5.3	Mount 1982
Cladoceran, *Dapnia magna* mixed ages	S,M	LC50	2.08	8.2	25	7.0-8.5	Parkhurst et al. 1979, 1981
Cladoceran, *Daphnia magna* <24-h	S,M	LC50	.53	7.4-8.15	19.6-22.8	6.8-8.0	Russo et al. 1985
Cladoceran, *Daphnia magna* <24-h	FT,M	LC50	4.94	8.11-8.58	19.7	95% saturated	Reinbold & Pescitelli 1982a
Cladoceran, *Daphnia magna* 48-h	S,M	LC50	2.94	8.4-8.6	19.5-20.5	8.8-9.2	Gersich & Hopkins 1986
Cladoceran, *Daphnia pullcaria*	FT,M	LC50	1.16	8.0-8.1	14	7.2-7.4	DeGraeve et al. 1980
Cladoceran, *Simocephalus vetulus* <24-h	FT,M	LC50	0.613	7.06	24	4.8-5.3	Mount 1982
Cladoceran, *Simocephalus vetulus*	FT,M	LC50	2.29	8.3	17.0	9.5	West 1985
Isopod, *Asellus racovitzai racovitzai* 12mm	FT,M	LC50	2.94	7.81	11.9	9.1	Thurston et al. 1983

Table . Continued

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Isopod, *Asellus racovitzai*	FT,M	LC50	4.95	8.0	4.0	12.6	West 1985
Amphipod, *Crangonyx pseudogracilis*	FT,M	LC50	1.63	8.0-8.2	4.0-24.9	7.1-12.6	West 1985
Crayfish, *Orconectes nais* 2.78cm	FT,M	LC50	3.15	7.6-9.0	26-27	7.8-8.2	Evans 1979
Crayfish, *Orconectes immunis*	FT,M	LC50	22.8	8.2	4.6	12.4	West 1985
Mayfly, *Callibaetis* sp. near *montanus* 10mm	FT,M	LC50	1.80	7.81	11.9	9.1	Thurston et al. 1984a
Mayfly, *Callibaetis skokianus* Nymph	FT,M	LC50	4.82	7.9	13.3	10.3	West 1985
Mayfly, *Ephamerella grandis* 10mm	FT,M	LC50	3.86	7.84-7.85	12.0-12.2	8.3-8.8	Thurston et al. 1984a
Stonefly, *Arcynopteryx parallela* 19mm	FT,M	LC50	2.00	7.76-7.81	13.1-13.8	8.5-8.9	Thurston et al. 1984a
Caddisfly, *Philarctus quaeris* Larvae	FT,M	LC50	10.2	7.8	13.3	10.4	West 1985
Beetle, *Stenelmis sexlineata* 2.8mm	FT,M	LC50	8.00	8.7	25	8.0	Hazel et al. 1979
Pink salmon, *Oncorhynchus gorbuscha* Late alevins	S,M	LC50	0.083	6.3-6.5	3.7-4.8		Rice & Bailey 1980
Coho salmon, *Oncorhynchus kisutch* Juvenile	FT,M	LC50	0.272	7.0-8.5			Robinson-Wilson & Seim 1975
Coho salmon, *Oncorhynchus kisutch*	FT,M	LC50	0.55	8.04-8.20	14.7	>80% saturated	Buckley 1978
Chinook salmon, *Oncorhynchus tshawytscha*	FT,M	LC50	.99	7.82-7.87	12.2-13.5	7.26-7.87	Thurston & Meyn 1984

Table . Continued

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Golden trout, *Salmo aquabonita* 0.09g	FT,M	LC50	0.755	8.06	13.2	8.9	Thurston & Russo 1981
Cutthroat trout, *Salmo clarki*	FT,M	LC50	0.52	7.78-7.81	12.2-13.1	8.3-8.6	Thurston et al., 1978
Rainbow trout, *Salmo gairdneri* 1d-51d	FT,M	LC50	0.160	7.4	14.5	>80% saturated	Calamari et al. 1977, 1981
Rainbow trout, *Salmo gairdneri* 1.48g	FT,M	LC50	0.697	7.95	10	80%	Broderius & Smith 1979
Rainbow trout, *Salmo gairdneri*	S,M	LC50	0.4	7.5	15	Aerated	Holt & Malcolm 1979
Rainbow trout, *Salmo gairdneri*	FT,M	LC50	0.77	8.0-8.1	14	7.2-7.4	DeGraeve et al. 1980
Rainbow trout, *Salmo gairdneri* .06g-2596g		LC50	0.163	7.62-8.08	7.9-14.5	6.6-9.4	Thurston & Russo 1983
Rainbow trout, *Salmo gairdneri*	FT,M	LC50	0.158	6.51-9.01	13.9-14.5	7.4-8.1	Thurston et al. 1981c
Rainbow trout, *Salmo gairdneri*	FT,M	LC50	0.497	7.75-7.83	12.5-12.9	5.66-7.57	Thurston et al. 1981b
Rainbow trout, *Salmo gairdneri*			0.40	8.30-8.56	3.0	86-100% saturated	Reinbold & Pescitelli 1982b
Rainbow trout, *Salmo gairdneri* 3.3g-22.4g	FT,M	LC50	0.26	7.7-8.3	3.6-18.7	7.3-9.6	West 1985
Brown trout, *Salmo trutta*	FT,M	LC50	0.597	7.82-7.86	13.2-14.2	8.65-9.28	Thurston & Meyn 1984
Book trout, *Salvellnus fontinalis*	FT,M	LC50	0.962	7.83-7.84	10.6-13.6	8.48-8.65	Thurston & Meyn 1984
Mountain whitefish, *Prosopium williamsoni*	FT,M	LC50	0.143	7.68-7.84	12.1-12.4	6.19-7.74	Thurston & Meyn 1984
Golden shiner, *Notemigonus crysoieucas*	FT,M	LC50	0.72	7.5	24.5	7.7	Swigert & Spacie 1983
Red shiner, *Notropis lutrensis*	FT,M	LC50	2.83	8.2-9.2	24	7.5-8.2	Hazel et al. 1979
Spotfin shiner, *Notropis spilopterus*	FT,M	LC50	1.20	7.7-8.5	26.5	81-89%	Rosage et al. 1979

Table . Continued

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Spotfin shiner, *Notropis spilopterus*	FT,M	LC50	1.35	7.9	25.7	7.3	Swigert & Spacie 1983
Steelcolour shiner, *Notropis whipplei*	FT,M	LC50	1.25	7.9	25.7	6.4	Swigert & Spacie 1983
Stoneroller, *Campostoma anonaium*	FT,M	LC50	1.72	7.8	25.7	6.4	Swigert & Spacie 1983
Fathead minnow, *Pimephaies promelas*	FT,M	LC50	1.59	8.0-8.1	14	7.2-7.4	DeGraeve et al. 1980
Fathead minnow, *Pimephales promelas* .09-2.39g	FT,M	LC50	0.754	7.63-8.16	12.8-22.4	6.2-9.0	Thurston et al. 1983
Fathead minnow, *Pimephales promelas* 1.8-2.0g	FT,M	LC50	0.240	6.51-9.03	11.8-13.8	9.3-9.9	Thurston et al. 1981c
Fathead minnow, *Pimephales promelas* 0.30-.066g	FT,M	LC50	0.73	7.86-8.70	4.1-25.2	73-96% saturated	Reinbold & Pescitelli 1982b
Fathead minnow, *Pimephales promelas* 0.2-0.5g	FT,M	LC50	1.75	7.78-7.80	25.6-25.9	7.1-7.2	Swigert & Spacie 1983
Fathead minnow, *Pimephales promelas* 1.6-1.9g	FT,M	LC50	1.83	8.0-8.1	12.1-26.1	6.3-9.8	West 1985
Fathead minnow, *Pimephales promelas* juvenile	S,M	LC50		8.2-8.5	22		Mayes et al. 1986 Alexander et al. 1985
White sucker, *Catosomus commersoni* 6.3g	FT,M	LC50	1.35	8.00-8.28	15.0-15.4	88-93% saturated	Reinbold & Pescitelli 1982c
White sucker, *Catosomus commersoni*	FT,M	LC50	0.79	7.8	22.5	7.4	Swigert & Spacie 1983
White sucker, *Catosomus commersoni* 5.2-96g	FT,M	LC50	0.76	7.8-8.2	3.6-15.3	9.2-12.5	West 1985
Mountain sucker, *Catostomus platyrhynchus*	FT,M	LC50	0.668	7.67-7.73	11.7-13.2	6.59-7.45	Thurston & Meyn 1984
Channel catfish, *Ictalurus punctatus*	S,U	LC50	2.4	8.34-8.8	22-30	Near saturation	Colt & Tchobanoglous 1976
Channel catfish, *Ictalurus punctatus*	FT,M	LC50	2.1	7.77-8.41	22-28	80-89% saturated	Roseboom & Richey 1977
Channel catfish, *Ictalurus punctatus*	FT,M	LC50	1.75	7.77-8.12	23.8	88% saturated	Reinbold & Pescitelli 1982d

Table . Continued

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Channel catfish, Ictalurus punctatus	FT,M	LC50	1.45	7.8	25.7	7.1	Swigert & Spacie 1983
Channel catfish, Ictalurus punctatus	FT,M	LC50	0.50	7.8-8.1	3.5-26.0	4.5-12.7	West 1985
Guppy, Poecilia reticulata	S,M	LC50	1.45	6.95-7.50	25	6.8-8.2	Rubin & Elmaraghy 1976, 1977
White perch, Morone americana	S,M	LC50	0.15	6.0	16		Stevenson 1977
Green sunfish, Lepomis cyanelius	FT,M	LC50	0.61	7.84	12.3	8.3	Jude 1973
Green sunfish, Lepomis cyanelius 9d	FT,M	LC50	1.08	8.09-8.46	26.2	88% saturated	Reinbold & Pescitelli 1982a
Green sunfish, Lepomis cyanelius	FT,M	LC50	0.59	6.6-8.7	22.4	8.1	McCormick et al. 1984
Pumpkinseed, Lepomis gibbosus	FT,M	LC50	0.14	7.77	12.0	8.4	Jude 1973
Pumpkinseed, Lepomis gibbosus	FT,M	LC50	0.61	7.71-7.77	14.0-15.7	7.16-8.37	Thurston 1981
Bluegill, Lepomis macrochirus	FT,M	LC50	0.89	7.96-9.00	18.5	9.1	Emery & Welch 1969
Bluegill, Lepomis macrochirus .072-.646g	FT,M	LC50	0.55	7.89-8.28	22-28	91-95% saturated	Roseboom & Richey 1977
Bluegill, Lepomis macrochirus 0.250g	FT,M	LC50	.26	7.98-8.47	4.5-25.0	74-100% saturated	Reinbold & Pescitelli 1982b
Bluegill, Lepomis macrochirus 49.2mg	FT,M	LC50	0.94	7.60	21.7	7.89	Smith et al. 1984
Bluegill, Lepomis macrochirus	FT,M	LC50	1.35	7.6-7.8	24.2-26.5	6.4-7.2	Swigert & Spacie 1983
Bluegill, Lepomis macrochirus juvenile	S,M	LC50	1.04	8.2-8.5	22		Mayes et al. 1986 Alexander et al. 1985
Smallmouth bass, Micropterus dolomieui 265mg	FT,M	LC50	0.694	6.53-8.71	22.3	7.93-8.00	Broderius et al. 1985
Largemouth bass, Micropterus salmoides 2.0-6.3g	FT,M	LC50	1.0	7.82-8.11	22-28	83-94% saturated	Roseboom & Richey 1977

Table . Continued

Species[1]	Test Conditions[2]	Effect[3]	Concentrn[4] (mg/L NH_3)	pH	Temperature (°C)	D.O. (mg/L)	Reference
Orangethroat darter, _Etheostoma spectabile_ 0.78g	FT,M	LC50	.90	7.7-8.5	21-22	7.6-8.1	Hazel et al. 1979
Walleye, _Stizostedion vitreum vitreum_ 6-d old	FT,M	LC50	.85	7.84-8.31	18.2	97% saturated	Reinbold & Pescitelli 1982a
Walleye, _Stizostedion vitreum_ 13.4-22.6g	FT,M	LC50	.51	7.7-8.3	3.7-19.0	6.9-11.7	West 1985
Walleye, _Stizostedion vitreum_	S,M	LC50	1.06	8.2-8.5	22		Mayes et al. 1986 Alexander et al. 1985
Mottled sculpin, _Cottus bairdi_ 1.8g	FT,M	LC50	1.39	8.02	12.4	8.9	Thurston & Russo 1981

Legend:

1. Adult unless otherwise stated
2. FT = flow-through, S = static, R = renewal, M = measured, U = unmeasured
3. Duration of exposure for invertebrates either 48 h or 96 h; duration of exposure for fishes 96 h.
4. Lowest recorded effect concentration

APPENDIX F

FISH SPECIES

IN ONTARIO RIVERS

Table. Summary of fish species present in select Ontario Rivers. Species name and common name are included. * denotes a cold water fish or a salmonid.

LYNDE CREEK (C)

Lampetra lamottei	American brook lamprey
Salmo gairdneri	Rainbow trout
Clinostomus elongatus	Redside dace
Notropis atherinoides	Emerald shiner
Notropis spilopterus	Spotfin shiner
N. stramineus	Sand shiner
Phoxinus eos	Northern redbelly dace
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Lepomis gibbosus	Pumpkinseed
Etheostoma caeruleum	Rainbow darter
E. niegrum	Johnny darter
Percina caprodes	Logperch
Notropis rubellus	Rosyface shiner

OSHAWA CREEK (C)

Lampetra lamottei	American brook lamprey
Notropis rubellus	Rosyface shiner
N. stamineus	Sand shiner
Phoxinus eos	Northern redbelly dace
Rhinichthys cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Notropis atherinoides	Emerald shiner
N. spilopterus	Spotfin shiner
Catostomus commersoni	White sucker
Petromyzon marinus	Sea lamprey
*Salmo gairdneri	Rainbow trout

WILMOT CREEK (C)

*Oncorhynchus kisutch	Coho salmon
*Oncorhynchus tshawytscha	Chinook salmon
*Salmo gairdneri	Rainbow trout
*S. trutta	Brown trout
Noturus flauus	Stonecat
Notropis cornutus	Common shiner
N. heterolepis	Blacknose shiner
Pimephales notatus	Bluntnose minnow

SHELTER VALLEY BROOK (C)

*Salmo gairdneri	Rainbow trout
Phoxinus eos	Northern redbelly dace
P. neogaeus	Finescale dace
Pimephales notatus	Bluntnose dace
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Culaea inconstans	Brook stickleback
Cottus bairdi	Mottled sculpin
Etheostoma flabellare	Fantail darter
E. nigrum	Johnny darter
Alosa pseudoharengus	Alewife
*Oncorhynchus tshawytscha	Chinook salmon
Notropis atherinoides	Emerald shiner
N. stramineus	Sand shiner
Ictalurus nebulosus	Brown Bullhead
*Cottus cognatus	Slimy sculpin
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
*Salvelinus fontinalis	Brook trout

GRINDSTONE CREEK (WC/C)

Hybognathus hankinsoni	Brassy minnow
Notropis cornutus	Common shiner
N. heterolepis	Blacknose minnow
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Lepomis gibbosus	Pumpkinseed
Micropterus dolomieui	Smallmouth bass
Etheostoma nigrum	Johnny darter

NITH RIVER

Clinostomus elongatus (1952)	Redside dace
Cyprinus carpio	Carp
Hybognathus hankinsoni	Brassy minnow
Nocomis biguttatus	Hornyhead chub
N. micropogon	River chub
Notropis chrysocephalus	Striped shiner
N. cornutus	Common shiner
N. photogenis	Silver shiner
N. rubellus	Rosyface shiner
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Semotilus atromaculatus	Creek chub
Hypentelium nigricans	Northern hog sucker
Moxostoma erythrurum	Golden redhorse
Ambloplites rupestris	Rock bass
Micropterus dolomieui	Smallmouth bass
Lepomis cyanellus	Green sunfish
Noturus flavus	Stonecat

COLDWATER RIVER (C)

*Oncorhynchus kisutch	Coho salmon
*Oncorhynchus tshawytscha	Chinook salmon
* Salmo gairnderi	Rainbow trout
* Salvelinus fontinalis	Brook trout
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Culaea inconstans	Brook Stickleback
Cottus bairdi	Mottled sculpin
Etheostoma nigrum	Johnny darter

HOLLAND RIVER (C)

Cyprinus carpio	Carp
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
N. cornutus	Common shiner
N. hudsonius	Spottail shiner
N. spilopterus	Spotfin shiner
Phoxinus eos	Northern redbelly dace
Pimephales notatus	Bluntnose minnow
Carpiodes cyprinus	Quillback
Ictalurus punctatus	Channel catfish
Percopsis omiscomaycus	Troutperch
Cottus bairdi	Mottled sculpin
Lepomis gibbosus	Pumpkinseed

BEAVERTON RIVER (C)

Notropis cornutus	Common shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Culaea inconstams	Brook stickleback
Pimephales promelas	Fathead minnow
Umbra limi	Mudminnow
Phoxinus neogaeus	Finescale dace
Semotilus margarita	Pearl dace

TWENTY MILE CREEK (WC)

Rhinichthys cataractae	Longnose dace
Dorosoma cepedianum	Gizzard shad
Labidesthes sicculus	Brook silverside
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
L. gibbosus	Pumpkinseed
L. macrochirus	Bluegill
Micropterus salmoides	Largemouth bass
Ictalurus melas	Black bullhead
Pomoxis nigromaculatus	Black crappie
Esox americanus vermiculatus	Grass pickeral
Etheostoma exile	Iowa darter
Notemigonus crysoleucas	Golden shiner
Pimephales notatus	Bluntnose minnow
Ictalurus nebulosus	Brown bullhead
Umbra limi	Mudminnow
Esox lucius	Northern pike
Culaea inconstans	Brook stickleback

ETOBICOKE CREEK (C)

Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
N. cornutus	Common shiner
N. heterolepis	Blacknose shiner
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Culaea inconstans	Brook stickleback
Ambloplites rupestris	Rock bass
Etheostoma flabellare	Fantail darter
E. nigrum	Johnny darter

MIMICO CREEK (C)

Couesius plumbeus	Lake chub
Notropis cornutus	Common shiner
N. hudsonius	Spottail shiner
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Culaea inconstans	Brook stickleback

HUMBER RIVER (C)

Alosa pseudoharengus	Alewife
Dorosoma cepedianum	Gizzard shad
Osmerus mordax	Rainbow smelt
Clinostomus elongatus	Redside dace
Nocomis micropogon	River chub
Notropis cornutus	Common shiner
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Cottus bairdi	Mottled sculpin
Morone chrysops	White bass
Etheostoma caeruleum	Rainbow darter
E. flabellare	Fantail darter
E. nigrum	Johnny darter
Notropis atherinoides	Emerald shiner
Gasterosteus aculeatus	Three spine stickleback
Notropis rubellus	Rosyface shiner

EAST HUMBER RIVER (C)

Lampetra lamottei	American brook lamprey
Clinostomus elongatus	Redside dace
Nocomis micropogon	River chub
Notropis cornutus	Common shiner
N. rubellus	Rosyface shiner
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Cotus bairdi	Mottled sculpin

Etheostoma caeruleum	Rainbow darter
E. flabellare	Fantail darter
E. nigrum	Johnny darter
Nocomis biguttatus	Hornyhead chub

DON RIVER (C)

Clinostomus elongatus	Redside dace
Notropis cornutus	Common shiner
Phoxinus eos	Northern redbelly dace
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Etheostoma nigrum	Johnny darter

HIGHLAND CREEK (L)

Lampetra lamottei	Northern brook lamprey
Clinostomus elongatus	Redside dace
Cyprinus carpio	Carp
Notropis cornutus	Common shiner
N. hudsonius	Spottail shiner
N. rubellus	Rosyface shiner
N. spilopterus	Spotfin shiner
N. stramineus	Sand shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
Noturus gyrinus	Tadpole madtom
Morone americana	White perch
Micropterus salmoides	Largemouth bass
Etheostoma caeruleum	Rainbow darter
E. nigrum	Johnny darter

SYDENHAM RIVER (SW)

Notropis chrysocephalus	Striped shiner
N. volucellus	Mimic shiner
Hypentelium nigricans	Northern hog sucker
Moxostoma erythrurum	Golden redhorse
M. anisurum	Silver redhorse
Cottus bairdi	Mottled sculpin
Notropis umbratilus	Redfin shiner
Etheostoma nigrum	Johnny darter
Percina maculata	Blackside darter

Notropis spilopterus	Spotfin shiner
Hiodon tergisus	Mooneye
Morone chrysops	White bass
Lepomis cyanellus	Green sunfish
Minytrema melanops	Spotted sucker
Pomixis nigromaculatus	Black crappie
Percina caprodes	Logperch
Aplodinotus grunniens	Freshwater drum
Pimephales notatus	Bluntnose minnow
Labidesthes sicculus	Brook silverside
Pomoxis annularis	White crappie

DINGMAN CREEK (SW)

Notropis chrysocephalus	Striped shiner
Moxostoma erythrurum ?	Golden redhorse
M. macrolepidotum	Shorthead redhorse

BIG OTTER CREEK (SW)

Rhinichthys atratulus	Blacknose dace
Noturus flavus	Stonecat
Percina maculata	Blackside darter
Notropis rubellus	Rosyface shiner
N. spilopterus	Spotfin shiner
Pimephales notatus	Bluntnose minnow
Etheostoma microperca	Least darter
Ammocrypta pellucida	Eastern sand darter
Ambloplites rupestris	Rock bass

CATFISH CREEK (SW)

Carassius auratus	Coldfish
Cyprinus carpio	Carp
Hybognathus hankinsoni	Brassy minnow
Notropis cornutus	Common shiner
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Semotilus atromaculatus	Creek chub
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Moxostoma erythrurum	Golden redhorse
Ambloplites rupestris	Rock bass
Etheostoma nigrum	Johnny darter
Percina maculata	Blackside darter
Notropis spilopterus	Spotfin shiner
Ictalurus natalis	Yellow bullhead

Noturus flavus	Stonecat
Dorosoma cepedianum	Gizzard shad
Ictalurus melas	Black bullhead
Moxostoma valenciennesi	Greater redhorse

SAUBLE RIVER (SW)

*Oncorhynchus tshawytscha	Chinook salmon
*Salmo gairdneri	Rainbow trout
*Salvelinus fontinalis	Brook trout
Esox lucius	Northern pike
Umbra limi	Mudminnow
Nocomis biguttatus	Hornyhead chub
N. micropogon	River chub
Notropis cornutus	Common shiner
N. heterolepis	Blacknose shiner
N. rubellus	Rosyface shiner
N. spilopterus	Spotfin shiner
N. umbratilis	Redfin shiner
Phoxinus eos	Northern redbelly dace
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
S. margarita	Pearl dace
Catostomus commersoni	White sucker
Moxostoma valenciennesi	Greater redhorse
Ictalurus melas	Black bullhead
I. nebulosus	Brown bullhead
Noturus flavus	Stonecat
Fundulus diaphanus	Banded killifish
Culaea inconstans	Brook stickleback
Cottus bairdi	Mottled sculpin
Ambloplites rupestris	Rock bass
Lepomis gibbosus	Pumpkinseed
L. megalotis	Longear sunfish
Micropterus dolomieui	Smallmouth bass
M. salmoides	Largemouth bass
Etheostoma caeruleum	Rainbow darter
E. microperca	Least darter
E. nigrum	Johnny darter
Percina maculata	Blackside darter
*Cottus cognatus	Slimy sculpin
Etheostoma exile	Iowa darter
*Oncorhynchus kisutch	Coho salmon

SAUGEEN RIVER (SW)

Ichthyomyzon fossor	Northern brook lamprey
Dorosoma cepedianum	Gizzard shad
*Salmo gairdneri	Rainbow trout
*Salmo trutta	Brown trout
*Salvelinus fontinalis	Brook trout
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Umbra limi	Mudminnow
Clinostomus elongatus	Redside dace
Cyprinus carpio	Carp
Hybognathus hankinsoni	Brassy minnow
Nocomis biguttatus	Hornyhead chub
N. micropogon	River chub
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
N. cornutus	Common shiner
N. heterodon	Blackchin shiner
N. heterolepis	Blacknose shiner
N. hudsonius	Spottail shiner
N. rubellus	Rosyface shiner
N. spilopterus	Spotfin shiner
N. umbratilus	Redfin shiner
N. volucellus	Mimic shiner
Phoxinus eos	Northern redbelly dace
P. neogaeus	Finescale dace
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
R. cataractae	Longnose dace
Semotilus atromaculatus	Greek chub
S. margarita	Pearl dace
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Moxostoma erythrurum	Golden redhorse
Ictalurus natalis	Yellow bullhead
I. nebulosus	Brown bullhead
Noturus flavus	Stonecat
N. gyrinus	Tadpole madtom
Fundulus diaphanus	Banded killifish
Culaea inconstans	Brook stickleback
Cottus bairdi	Mottled sculpin
*C. cognatus	Slimy sculpin
Ambloplites rupestris	Rock bass
Lepomis gibbosus	Pumpkinseed
L. megalotis	Longear sunfish
Micropterus salmoides	Largemouth bass
Etheostoma caeruleum	Rainbow darter
E. exile	Iowa darter
E. flabellare	Fantail darter
E. microperca	Least darter
E. nigrum	Johnny darter
Perca flavescens	Yellow perch

Percina caprodes	Logperch
P. maculata	Blackside darter
Lepomis macrochirus	Bluegill
*Salvelinus namaycush	Lake trout

APPENDIX G

AMMONIA WATER QUALITY OBJECTIVES

(i) Criteria Specified By Other Agencies
(ii) CCC and CMC Ammonia Concentrations for Rivers in Ontario
(iii) Exceedences of CCC and CMC Criteria for Rivers in Ontario

APPENDIX G
WATER QUALITY DATA

Water quality data for the selected rivers was obtained from the Provincial Water Quality Monitoring Network (PWQMN). Ammonia concentrations were converted to un-ionized ammonia by the formula of Emerson et al (1975) indicated earlier. The amount of un-ionized ammonia present in surface waters is dependent on pH and temperature of the water sample. Laboratory pH was used in the formula only when field pH was not present. Although field pH was significantly lower than laboratory pH ($p < 0.5$), un-ionized ammonia calculated using field pH was not significantly different from the ammonia calculated using laboratory pH ($p > 0.5$).

Mean un-ionized ammonia concentrations for the rivers ranged from 0.002 to 0.0135 mg/L. The variability of un-ionized ammonia in the rivers was greater than the variability between rivers (F test, $p < 0.5$) suggesting that within a water body un-ionized ammonia concentrations can fluctuate widely. Regionally, of the stations used in the study, rivers in Central Ontario had higher ammonia concentrations. The water quality stations with the highest concentrations were situated downstream of municipal sewage treatment plants. High un-ionized ammonia levels occurred in the Don River, Grindstone Creek and the Holland River.

The effect of ammonia can be significant on the quality and abundance of aquatic life. However, it is a difficult parameter to accurately measure because of its dependence on ambient temperature and pH conditions. Unfortunately, the period of record of reliable water quality data was found to be short, and for some stations inadequate, to establish reliable estimates of U.S. EPA CCC and CMC concentrations. Should additional research be undertaken in this area in the future, lengthier data bases will be required to establish firm estimates of these parameters, particularly if the pollutant being used is ammonia. A lengthier data base will also be required for establishing reliable background concentrations for performing wasteload allocation calculations.

The results of the investigation of design low flows and pollutant concentrations indicate that current MOE design standards ($7Q_{20}$ and the "Blue Book" objectives for ammonia concentration of 0.02 mg/L) are equivalent to, or exceed the low flow and pollutant concentration requirements defined by the U.S. EPA's biological methodologies.

Comparison of existing ammonia water quality criteria in different agencies.

Agency	Conditions	Ammonia Criterion (mg/L)
MOE (1984)	unionized ammonia	0.02
Manitoba (1983)	un-ionized ammonia	0.02
IJC (1986)	un-ionized ammonia	0.03
IJC (1986)[1]	un-ionized ammonia, for limited use (<96 hr) zones which overlap with routes of passage.	varies with pH
CCREM (1987)[2]	total ammonia, 4 day average	varies with pH, and temperature
US EPA (1985)[3]	unionized ammonia, one hour average not to be exceeded more often than once every 3 yrs on average	varies with pH, temperature and presence of sensitive cold-water fish species
US EPA (1985)[2]	un-ionized ammonia, 4 day average not to be exceeded more often than once every 3 yrs on average	varies with pH, temperature and presence of sensitive cold-water fish species
EIFAC (1980)	un-ionized ammonia	0.025

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1. from formula: $NH_3(mg/L) = 0.3 \times \frac{0.66}{1+10^{(1.03(7.32-pH))}}$

2. from formula: $NH_3(mg/L) = 0.80/FT/FPH/RATIO$

   $\%NH_3 \text{ in } NH_4 = \frac{1}{1+10^{(pka-pH)}}$

   (for further definitions see Table ?)

3. from formula: $NH_3(mg/L) = 0.52/FT/FPH/2$

   (for further definitions see Table ?)

US EPA National Ammonia Criteria Formula (US EPA 1985)

CMC = the one-hour average concentration of un-ionized ammonia (mg/L NH_3) not to be exceeded, more than once every three years on the average.

$= 0.52/FT/FPH/Z$

where;

$FT = 10^{0.03(20-TCAP)}$; $TCAP \le T \le 30$
$= 10^{0.03(20-T)}$; $0 \le T \le TCAP$

$FPH = 1$; $8 \le pH \le 9$
$= \dfrac{1 + 10^{7.4-pH}}{1.25}$; $6.5 \le pH \le 8$

TCAP = 20°C; salmonids or other sensitive cold=water fish species present.

= 25°C; salmonids or other sensitive cold-water fish species absent.

CCC = the 4-day average concentration of un-ionized ammonia (mg/L NH_3) not to be exceeded, more than once every three years on the average.

$= 0.80/FT/FPH/RATIO$

where:

$FT = 10^{0.03(20-TCAP)}$; $TCAP \le T \le 30$
$= 10^{0.03(20-T)}$; $0 \le T \le TCAP$

$RATIO = 16$; $7.7 \le pH \le 9$
$= \dfrac{24 \times 10^{7.7-pH}}{1 + 10^{7.4-pH}}$; $6.5 \le pH \le 7.7$

TCAP = 15°C; salmonids or other sensitive cold-water fish species present.

= 20°C; salmonids or other sensitive cold-water fish species absent.

Summary of Calculated Unionized Ammonia USEPA Criteria for selected Ontario Rivers

River	Region	CCC (mg/L)	CMC (mg/L)
Lynde Creek	C	0.024	0.144
Oshawa Creek	C	0.024	0.142
Wilmot Creek	C	0.024	0.137
Shelter Valley Brook	C	0.025	0.141
Grindstone Creek	WC/C	0.032	0.185
Nith River	WC	0.030	0.164
Coldwater River	C	0.021	0.125
Holland River	C	0.027	0.152
Beaverton River	C	0.026	0.151
Twenty Mile Creek	WC	0.029	0.160
Etobicoke Creek	C	0.030	0.160
Mimico Creek	C	0.027	0.166
Humber River	C	0.022	0.119
East Humber River	C	0.023	0.129
Don River (Lakeshore Rd.)	C	0.024	0.132
Don River (Bayview Exit)	C	0.022	0.121
Highland Creek	C	0.025	0.135
Sydenham River	SW	0.025	0.146
Dingman Creek	SW	0.023	0.122
Big Otter Creek	SW	0.029	0.150
Catfish Creek	SW	0.043	0.254
Sable River	SW	0.025	0.151
Saugeen River	SW	0.027	0.164

Exeedances of Unionized Ammonia Criteria for selected Ontario Rivers.
(n = number of days where unionized ammonia data available)

River	Region	Time Period	Ammonia	Criteria		Exceedances	
			n	MOE	IJC	CCREM	USEPA
Lynde Creek	C	83/09/09 - 86/09/09	34	0	0	0	0
Oshawe Creek	C	83/09/09 - 86/11/17	36	1	0	1	0
Wilmot Creek	C	83/09/09 - 86/11/17	33	0	0	0	0
Shelter Valley Brook	C	83/09/08 - 86/11/24	32	0	0	0	0
Grindstone Creek	WC/C	83/09/27 - 86/11/25	32	3	3	3	2
Nith River	WC	83/09/28 - 86/11/12	35	0	0	0	0
Coldwater River	C	83/09/28 - 86/10/23	33	0	0	0	0
Holland River	C	83/09/19 - 86/11/18	35	11	8	9	7
Beaverton River	C	83/09/27 - 86/10/22	34	0	0	0	0
Twenty Mile Creek	WC	83/09/08 - 86/11/25	38	0	0	0	0
Etobicoke Creek	C	83/09/14 - 86/11/26	36	2	1	1	0
Mimico Creek	C	83/09/07 - 86/11/18	35	0	0	0	0
Humber River	C	83/09/07 - 86/11/18	36	0	0	0	0
East Humber River	C	83/09/07 - 86/11/18	34	0	0	0	0
Don River (Lakeshore Rd.)	C	83/09/14 - 86/11/26	45	21	10	17	15
Don River (Bayview Exit)	C	83/09/07 - 86/11/27	42	13	7	10	8
Highland Creek	C	83/09/29 - 86/11/19	35	0	0	0	0
Sydenham River	SW	83/09/13 - 84/09/04	9	0	0	0	0
		70/03/31 - 83/08/09	78	0	0	0	0
Dingman Creek	SW	83/09/21 - 84/09/19	13	0	0	0	0
		77/03/23 - 83/08/17	46	0	0	0	0
Big Otter Creek	SW	83/09/29 - 84/07/19	9	0	0	0	0
		78/03/15 - 83/08/09	49	0	0	0	0
Catfish Creek	SW	83/09/19 - 84/08/28	5	0	0	0	0
		76/05/25 - 83/08/24	28	0	0	0	0
Sable River	SW	83/10/03 - 84/09/26	12	0	0	0	0
		70/02/04 - 83/08/23	128	0	0	0	0
Saugeen River	SW	83/09/19 - 84/09/17	11	0	0	0	0
		65/11/25 - 83/08/29	48	0	0	0	0

APPENDIX H

EVALUATION OF LOW FLOW METHODOLOGIES

(i) Hydrologically Defined Low Flows
(ii) Biologically Defined Low Flows
(iii) Application of Evaluation Criteria

Index for Interpreting Tables in this Appendix

Table # Name of River									
Hydrometric Station Number									
Period of Record		Max. No. of Excurs. Allow. for Period							
(1) CCC Design Flow =		(2) Number of Excursions Using CCC		Evaluation Criteria					
(3) CMC Design Flow =		(4) Number of Excursions Using CMC							
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	(5)-(1)	$\frac{(5)-(1)}{(5)}$ (m^3/s)	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2									
1-Q-10									
1-Q-20									
3-Q- 2									
3-Q-10									
3-Q-20									
7-Q- 2									
7-Q-10									
7-Q-20									
15-Q- 2									
15-Q-10									
15-Q-20									
30-Q- 2									
30-Q-10									
30-Q-20									

☐ Evaluation of Hydrologic Design Flow with respect to the CCC Design Flow

▨ Evaluation of Hydrologic Design Flow with respect to the CMC Design Flow

Index for Interpreting Tables in this Appendix

Column	Description
(a)	Hydrologic Design Flow Duration and Frequency Characteristics
(b)	Hydrologic Design Flow (cubic meters per second)
(c)	Number of Excursions Using the Hydrologic Flow Value as the CCC Design Flow
(d)	Number of Excursions Using the Hydrologic Flow Value as the CMC Design Flow
(e)	Magnitude of Increase in Number of Excursions Using Hydrologic Flow Value as CCC Design Low Flow
(f)	Difference Between Value of CCC Design Low Flow and Hydrologic Design Flow (m^3/s)
(g)	Relative Difference Between Value of CCC Design Low Flow and Hydrologic Design Flow
(h)	Magnitude of Increase in Number of Excursions Using Hydrologic Flow Value as CMC Design Low Flow
(i)	Difference Between Value of CMC Design Low Flow and Hydrologic Design Flow (m^3/s)
(j)	Relative Difference Between Value of CMC Design Low Flow and Hydrologic Design Flow

Table H.1 Neebing River

Hydrometric Station Number 02AB008

Period of Record 1954 - 1986		Max. No. of Excurs. Allow. =	10.9
(1) CCC Design Flow =	0.019	(2) Number of Excursions =	10.5
(3) CMC Design Flow =	0.014	(4) Number of Excursions =	7.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.052	77.3	83.0	7.36	0.033	0.63	11.86	0.038	0.73
1-Q- 5	0.022	14.5	16.0	1.38	0.003	0.14	2.29	0.008	0.36
1-Q-10	0.014	3.0	7.0	0.29	-0.005	-0.36	1.00	0.000	0.00
1-Q-20	0.010	0.0	1.0	0.00	-0.009	-0.90	0.14	-0.004	-0.40
3-Q- 2	0.058	89.3	99.0	8.50	0.039	0.67	14.14	0.044	0.76
3-Q- 5	0.027	18.5	21.0	1.76	0.008	0.30	3.00	0.013	0.48
3-Q-10	0.018	8.5	12.0	0.81	-0.001	-0.06	1.71	0.004	0.22
3-Q-20	0.014	3.0	7.0	0.29	-0.005	-0.36	1.00	0.000	0.00
7-Q- 2	0.062	93.5	103.0	8.90	0.043	0.69	14.71	0.048	0.77
7-Q- 5	0.029	46.3	64.0	4.40	0.010	0.34	9.14	0.015	0.52
7-Q-10	0.020	12.3	16.0	1.17	0.001	0.05	2.29	0.006	0.30
7-Q-20	0.016	6.0	11.0	0.57	-0.003	-0.19	1.57	0.002	0.13
15-Q- 2	0.070	102.5	111.0	9.76	0.051	0.73	15.86	0.056	0.80
15-Q- 5	0.034	52.8	64.0	5.02	0.015	0.44	9.14	0.020	0.59
15-Q-10	0.024	15.8	16.0	1.50	0.005	0.21	2.29	0.010	0.42
15-Q-20	0.019	10.5	15.0	1.00	0.000	0.00	2.14	0.005	0.26
30-Q- 2	0.081	113.5	142.0	10.81	0.062	0.77	20.29	0.067	0.83
30-Q- 5	0.045	63.5	74.0	6.05	0.026	0.58	10.57	0.031	0.69
30-Q-10	0.035	52.8	66.0	5.02	0.016	0.46	9.43	0.021	0.60
30-Q-20	0.030	47.0	64.0	4.48	0.011	0.37	9.14	0.016	0.53

Table H.2 Black River

Hydrometric Station Number 02BB002

Period of Record 1968 - 1986		Max. No. of Excurs. Allow. = 6.2	
(1) CCC Design Flow = 2.901		(2) Number of Excursions = 5.0	
(3) CMC Design Flow = 2.909		(4) Number of Excursions = 5.0	

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	3.959	40.8	50.0	8.15	1.058	0.27	10.00	1.050	0.27
1-Q- 5	3.341	13.0	15.0	2.60	0.440	0.13	3.00	0.432	0.13
1-Q-10	3.091	11.5	14.0	2.30	0.190	0.06	2.80	0.182	0.06
1-Q-20	2.926	7.3	10.0	1.45	0.025	0.01	2.00	0.017	0.01
3-Q- 2	3.974	41.8	50.0	8.35	1.073	0.27	10.00	1.065	0.27
3-Q- 5	3.351	13.8	15.0	2.75	0.450	0.13	3.00	0.442	0.13
3-Q-10	3.097	11.5	14.0	2.30	0.196	0.06	2.80	0.188	0.06
3-Q-20	2.928	7.5	10.0	1.50	0.027	0.01	2.00	0.019	0.01
7-Q- 2	4.010	44.3	50.0	8.85	1.109	0.28	10.00	1.101	0.27
7-Q- 5	3.382	15.0	15.0	3.00	0.481	0.14	3.00	0.473	0.14
7-Q-10	3.120	11.8	15.0	2.35	0.219	0.07	3.00	0.211	0.07
7-Q-20	2.945	7.8	10.0	1.55	0.044	0.01	2.00	0.036	0.01
15-Q- 2	4.100	51.5	56.0	10.30	1.199	0.29	11.20	1.191	0.29
15-Q- 5	3.447	15.0	15.0	3.00	0.546	0.16	3.00	0.538	0.16
15-Q-10	3.168	12.0	15.0	2.40	0.267	0.08	3.00	0.259	0.08
15-Q-20	2.977	8.5	10.0	1.70	0.076	0.03	2.00	0.068	0.02
30-Q- 2	4.256	56.3	60.0	11.25	1.355	0.32	12.00	1.347	0.32
30-Q- 5	3.568	22.5	26.0	4.50	0.667	0.19	5.20	0.659	0.18
30-Q-10	3.259	12.5	15.0	2.50	0.358	0.11	3.00	0.350	0.11
30-Q-20	3.040	11.3	13.0	2.25	0.139	0.05	2.60	0.131	0.04

Table H.3 Magpie River

Hydrometric Station Number 02BD003

Period of Record 1953 - 1986		Max. No. of Excurs. Allow. =	8.6
(1) CCC Design Flow =	2.838	(2) Number of Excursions =	8.5
(3) CMC Design Flow =	2.606	(4) Number of Excursions =	8.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	6.269	128.8	139.0	15.15	3.431	0.55	17.38	3.663	0.58
1-Q- 5	4.373	56.0	59.0	6.59	1.535	0.35	7.38	1.767	0.40
1-Q-10	3.497	16.5	19.0	1.94	0.659	0.19	2.38	0.891	0.25
1-Q-20	2.860	9.0	10.0	1.06	0.022	0.01	1.25	0.254	0.09
3-Q- 2	6.418	132.5	141.0	15.59	3.580	0.56	17.63	3.812	0.59
3-Q- 5	4.516	59.3	61.0	6.97	1.678	0.37	7.63	1.910	0.42
3-Q-10	3.605	24.3	27.0	2.85	0.767	0.21	3.38	0.999	0.28
3-Q-20	2.925	10.0	10.0	1.18	0.087	0.03	1.25	0.319	0.11
7-Q- 2	6.599	130.3	143.0	15.32	3.761	0.57	17.88	3.993	0.61
7-Q- 5	4.663	60.0	61.0	7.06	1.825	0.39	7.63	2.057	0.44
7-Q-10	3.710	27.3	31.0	3.21	0.872	0.24	3.88	1.104	0.30
7-Q-20	2.983	10.0	10.0	1.18	0.145	0.05	1.25	0.377	0.13
15-Q- 2	6.840	135.3	144.0	15.91	4.002	0.59	18.00	4.234	0.62
15-Q- 5	4.869	60.0	64.0	7.06	2.031	0.42	8.00	2.263	0.46
15-Q-10	3.865	32.3	39.0	3.79	1.027	0.27	4.88	1.259	0.33
15-Q-20	3.078	10.0	10.0	1.18	0.240	0.08	1.25	0.472	0.15
30-Q- 2	7.278	146.8	155.0	17.26	4.440	0.61	19.38	4.672	0.64
30-Q- 5	5.187	71.8	82.0	8.44	2.349	0.45	10.25	2.581	0.50
30-Q-10	4.065	46.8	50.0	5.50	1.227	0.30	6.25	1.459	0.36
30-Q-20	3.150	10.0	10.0	1.18	0.312	0.10	1.25	0.544	0.17

Table H.4 Batchawana River

Hydrometric Station Number 02BF001

Period of Record 1968 - 1986		Max. No. of Excurs. Allow. =	6.2
(1) CCC Design Flow =	1.822	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	1.795	(4) Number of Excursions =	5.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6)/(2)	(5)-(1) (m^3/s)	(5)-(1)/(5)	(7)/(4)	(5)-(3) (m^3/s)	(5)-(3)/(5)
1-Q- 2	3.544	37.5	43.0	6.25	1.722	0.49	8.60	1.749	0.49
1-Q- 5	2.458	22.0	26.0	3.67	0.636	0.26	5.20	0.663	0.27
1-Q-10	1.915	11.8	15.0	1.96	0.093	0.05	3.00	0.120	0.06
1-Q-20	1.497	2.0	4.0	0.33	-0.325	-0.22	0.80	-0.298	-0.20
3-Q- 2	3.595	40.0	46.0	6.67	1.773	0.49	9.20	1.800	0.50
3-Q- 5	2.501	22.5	29.0	3.75	0.679	0.27	5.80	0.706	0.28
3-Q-10	1.953	12.0	15.0	2.00	0.131	0.07	3.00	0.158	0.08
3-Q-20	1.530	2.5	5.0	0.42	-0.292	-0.19	1.00	-0.265	-0.17
7-Q- 2	3.696	43.3	49.0	7.21	1.874	0.51	9.80	1.901	0.51
7-Q- 5	2.588	23.8	30.0	3.96	0.766	0.30	6.00	0.793	0.31
7-Q-10	2.037	12.5	16.0	2.08	0.215	0.11	3.20	0.242	0.12
7-Q-20	1.612	4.5	5.0	0.75	-0.210	-0.13	1.00	-0.183	-0.11
15-Q- 2	3.935	47.8	50.0	7.96	2.113	0.54	10.00	2.140	0.54
15-Q- 5	2.773	25.0	30.0	4.17	0.951	0.34	6.00	0.978	0.35
15-Q-10	2.176	17.0	21.0	2.83	0.354	0.16	4.20	0.381	0.18
15-Q-20	1.707	5.0	5.0	0.83	-0.115	-0.07	1.00	-0.088	-0.05
30-Q- 2	4.226	45.8	61.0	7.63	2.404	0.57	12.20	2.431	0.58
30-Q- 5	2.984	26.5	30.0	4.42	1.162	0.39	6.00	1.189	0.40
30-Q-10	2.392	21.0	26.0	3.50	0.570	0.24	5.20	0.597	0.25
30-Q-20	1.951	12.0	15.0	2.00	0.129	0.07	3.00	0.156	0.08

Table H.5 Serpent River @ Hwy 17

Hydrometric Station Number 02CD001

Period of Record 1967 - 1986		Max. No. of Excurs. Allow. =	6.6
(1) CCC Design Flow =	0.611	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	0.595	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	2.912	35.5	40.0	5.92	2.301	0.79	6.67	2.317	0.80
1-Q- 5	1.485	22.8	25.0	3.79	0.874	0.59	4.17	0.890	0.60
1-Q-10	0.944	10.0	10.0	1.67	0.333	0.35	1.67	0.349	0.37
1-Q-20	0.607	6.0	9.0	1.00	-0.004	-0.01	1.50	0.012	0.02
3-Q- 2	2.954	37.5	40.0	6.25	2.343	0.79	6.67	2.359	0.80
3-Q- 5	1.512	23.3	25.0	3.88	0.901	0.60	4.17	0.917	0.61
3-Q-10	0.970	10.0	11.0	1.67	0.359	0.37	1.83	0.375	0.39
3-Q-20	0.632	7.3	10.0	1.21	0.021	0.03	1.67	0.037	0.06
7-Q- 2	3.045	42.5	47.0	7.08	2.434	0.80	7.83	2.450	0.80
7-Q- 5	1.574	24.0	25.0	4.00	0.963	0.61	4.17	0.979	0.62
7-Q-10	1.022	10.0	15.0	1.67	0.411	0.40	2.50	0.427	0.42
7-Q-20	0.680	8.0	10.0	1.33	0.069	0.10	1.67	0.085	0.13
15-Q- 2	3.237	50.8	60.0	8.46	2.626	0.81	10.00	2.642	0.82
15-Q- 5	1.712	24.8	28.0	4.13	1.101	0.64	4.67	1.117	0.65
15-Q-10	1.126	14.0	18.0	2.33	0.515	0.46	3.00	0.531	0.47
15-Q-20	0.756	9.0	10.0	1.50	0.145	0.19	1.67	0.161	0.21
30-Q- 2	3.505	52.5	55.0	8.75	2.894	0.83	9.17	2.910	0.83
30-Q- 5	1.874	26.8	29.0	4.46	1.263	0.67	4.83	1.279	0.68
30-Q-10	1.255	16.5	20.0	2.75	0.644	0.51	3.33	0.660	0.53
30-Q-20	0.867	10.0	10.0	1.67	0.256	0.30	1.67	0.272	0.31

Table H.6 Serpent River

Hydrometric Station Number 02CD006

Period of Record 1973 - 1986		Max. No. of Excurs. Allow. =	3.6
(1) CCC Design Flow =	0.397	(2) Number of Excursions =	3.5
(3) CMC Design Flow =	0.269	(4) Number of Excursions =	3.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	(5)-(1) (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.660	23.8	29.0	6.79	0.263	0.40	9.67	0.391	0.59
1-Q- 5	0.451	5.0	6.0	1.43	0.054	0.12	2.00	0.182	0.40
1-Q-10	0.359	2.8	5.0	0.79	-0.038	-0.11	1.67	0.090	0.25
1-Q-20	0.294	2.3	5.0	0.64	-0.103	-0.35	1.67	0.025	0.09
3-Q- 2	0.679	24.0	29.0	6.86	0.282	0.42	9.67	0.410	0.60
3-Q- 5	0.467	5.0	8.0	1.43	0.070	0.15	2.67	0.198	0.42
3-Q-10	0.375	3.0	5.0	0.86	-0.022	-0.06	1.67	0.106	0.28
3-Q-20	0.312	2.3	5.0	0.64	-0.085	-0.27	1.67	0.043	0.14
7-Q- 2	0.719	24.5	30.0	7.00	0.322	0.45	10.00	0.450	0.63
7-Q- 5	0.498	11.5	13.0	3.29	0.101	0.20	4.33	0.229	0.46
7-Q-10	0.400	4.0	5.0	1.14	0.003	0.01	1.67	0.131	0.33
7-Q-20	0.331	2.5	5.0	0.71	-0.066	-0.20	1.67	0.062	0.19
15-Q- 2	0.793	34.0	39.0	9.71	0.396	0.50	13.00	0.524	0.66
15-Q- 5	0.570	16.5	20.0	4.71	0.173	0.30	6.67	0.301	0.53
15-Q-10	0.467	5.0	8.0	1.43	0.070	0.15	2.67	0.198	0.42
15-Q-20	0.392	3.3	5.0	0.93	-0.005	-0.01	1.67	0.123	0.31
30-Q- 2	0.912	42.3	48.0	12.07	0.515	0.56	16.00	0.643	0.71
30-Q- 5	0.673	23.8	29.0	6.79	0.276	0.41	9.67	0.404	0.60
30-Q-10	0.556	15.0	17.0	4.29	0.159	0.29	5.67	0.287	0.52
30-Q-20	0.465	5.0	8.0	1.43	0.068	0.15	2.67	0.196	0.42

Table H.7 Whitson River

Hydrometric Station Number 02CF007

Period of Record 1961 - 1986 | Max. No. of Excurs. Allow. = 8.6

(1) CCC Design Flow = 0.367 | (2) Number of Excursions = 8.5

(3) CMC Design Flow = 0.343 | (4) Number of Excursions = 5.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	(5)-(1) (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.442	44.3	55.0	5.21	0.075	0.17	11.00	0.099	0.22
1-Q- 5	0.352	3.5	13.0	0.41	-0.015	-0.04	2.60	0.009	0.03
1-Q-10	0.322	0.0	2.0	0.00	-0.045	-0.14	0.40	-0.021	-0.07
1-Q-20	0.305	0.0	1.0	0.00	-0.062	-0.20	0.20	-0.038	-0.12
3-Q- 2	0.464	53.5	74.0	6.29	0.097	0.21	14.80	0.121	0.26
3-Q- 5	0.378	12.8	23.0	1.50	0.011	0.03	4.60	0.035	0.09
3-Q-10	0.350	2.3	10.0	0.26	-0.017	-0.05	2.00	0.007	0.02
3-Q-20	0.334	0.0	3.0	0.00	-0.033	-0.10	0.60	-0.009	-0.03
7-Q- 2	0.490	71.8	86.0	8.44	0.123	0.25	17.20	0.147	0.30
7-Q- 5	0.404	26.8	37.0	3.15	0.037	0.09	7.40	0.061	0.15
7-Q-10	0.376	10.5	22.0	1.24	0.009	0.02	4.40	0.033	0.09
7-Q-20	0.361	7.5	16.0	0.88	-0.006	-0.02	3.20	0.018	0.05
15-Q- 2	0.518	80.8	94.0	9.50	0.151	0.29	18.80	0.175	0.34
15-Q- 5	0.421	34.3	41.0	4.03	0.054	0.13	8.20	0.078	0.19
15-Q-10	0.390	19.3	32.0	2.26	0.023	0.06	6.40	0.047	0.12
15-Q-20	0.372	10.3	21.0	1.21	0.005	0.01	4.20	0.029	0.08
30-Q- 2	0.567	90.5	101.0	10.65	0.200	0.35	20.20	0.224	0.40
30-Q- 5	0.447	47.0	62.0	5.53	0.080	0.18	12.40	0.104	0.23
30-Q-10	0.409	28.5	38.0	3.35	0.042	0.10	7.60	0.066	0.16
30-Q-20	0.388	18.3	31.0	2.15	0.021	0.05	6.20	0.045	0.12

Table H.8 Duchesnay River										
Hydrometric Station Number 02DD008										
Period of Record 1957 - 1982		Max. No. of Excurs. Allow. =	8.6							
(1) CCC Design Flow =	0.044	(2) Number of Excursions =	8.5							
(3) CMC Design Flow =	0.025	(4) Number of Excursions =	8.0							
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.096	43.8	60.0	5.15	0.052	0.54	7.50	0.071	0.74
1-Q- 5	0.056	15.0	21.0	1.76	0.012	0.21	2.63	0.031	0.55
1-Q-10	0.036	7.5	12.0	0.88	-0.008	-0.22	1.50	0.011	0.31
1-Q-20	0.021	3.8	6.0	0.44	-0.023	-1.10	0.75	-0.004	-0.19
3-Q- 2	0.104	48.5	63.0	5.71	0.060	0.58	7.88	0.079	0.76
3-Q- 5	0.063	24.0	31.0	2.82	0.019	0.30	3.88	0.038	0.60
3-Q-10	0.043	8.5	15.0	1.00	-0.001	-0.02	1.88	0.018	0.42
3-Q-20	0.028	4.8	9.0	0.56	-0.016	-0.57	1.13	0.003	0.11
7-Q- 2	0.121	62.5	82.0	7.35	0.077	0.64	10.25	0.096	0.79
7-Q- 5	0.075	29.5	40.0	3.47	0.031	0.41	5.00	0.050	0.67
7-Q-10	0.053	12.0	15.0	1.41	0.009	0.17	1.88	0.028	0.53
7-Q-20	0.036	7.5	12.0	0.88	-0.008	-0.22	1.50	0.011	0.31
15-Q- 2	0.145	84.3	98.0	9.91	0.101	0.70	12.25	0.120	0.83
15-Q- 5	0.088	37.8	54.0	4.44	0.044	0.50	6.75	0.063	0.72
15-Q-10	0.064	24.8	31.0	2.91	0.020	0.31	3.88	0.039	0.61
15-Q-20	0.048	9.8	15.0	1.15	0.004	0.08	1.88	0.023	0.48
30-Q- 2	0.173	108.3	133.0	12.74	0.129	0.75	16.63	0.148	0.86
30-Q- 5	0.109	51.3	64.0	6.03	0.065	0.60	8.00	0.084	0.77
30-Q-10	0.086	37.3	53.0	4.38	0.042	0.49	6.63	0.061	0.71
30-Q-20	0.072	27.0	34.0	3.18	0.028	0.39	4.25	0.047	0.65

Table H.9 Holland River

Hydrometric Station Number 02EC009

Period of Record 1966 - 1986		Max. No. of Excurs. Allow. =	6.9
(1) CCC Design Flow =	0.140	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	0.119	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.238	25.8	40.0	4.29	0.098	0.41	6.67	0.119	0.50
1-Q- 5	0.170	12.3	20.0	2.04	0.030	0.18	3.33	0.051	0.30
1-Q-10	0.131	5.5	12.0	0.92	-0.009	-0.07	2.00	0.012	0.09
1-Q-20	0.099	0.0	3.0	0.00	-0.041	-0.41	0.50	-0.020	-0.20
3-Q- 2	0.261	37.8	56.0	6.29	0.121	0.46	9.33	0.142	0.54
3-Q- 5	0.187	14.0	20.0	2.33	0.047	0.25	3.33	0.068	0.36
3-Q-10	0.146	8.3	15.0	1.38	0.006	0.04	2.50	0.027	0.18
3-Q-20	0.110	1.3	4.0	0.21	-0.030	-0.27	0.67	-0.009	-0.08
7-Q- 2	0.293	57.0	70.0	9.50	0.153	0.52	11.67	0.174	0.59
7-Q- 5	0.221	21.0	33.0	3.50	0.081	0.37	5.50	0.102	0.46
7-Q-10	0.181	13.5	20.0	2.25	0.041	0.23	3.33	0.062	0.34
7-Q-20	0.149	8.8	15.0	1.46	0.009	0.06	2.50	0.030	0.20
15-Q- 2	0.327	67.3	84.0	11.21	0.187	0.57	14.00	0.208	0.64
15-Q- 5	0.252	32.5	52.0	5.42	0.112	0.44	8.67	0.133	0.53
15-Q-10	0.218	19.8	31.0	3.29	0.078	0.36	5.17	0.099	0.45
15-Q-20	0.192	14.5	20.0	2.42	0.052	0.27	3.33	0.073	0.38
30-Q- 2	0.376	113.5	160.0	18.92	0.236	0.63	26.67	0.257	0.68
30-Q- 5	0.295	57.3	71.0	9.54	0.155	0.53	11.83	0.176	0.60
30-Q-10	0.256	32.8	54.0	5.46	0.116	0.45	9.00	0.137	0.54
30-Q-20	0.225	22.5	38.0	3.75	0.085	0.38	6.33	0.106	0.47

Table H.10 Beaverton River

Hydrometric Station Number 02EC011

Period of Record 1967 - 1986		Max. No. of Excurs. Allow. =	6.6
(1) CCC Design Flow =	0.113	(2) Number of Excursions =	5.8
(3) CMC Design Flow =	0.105	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\underline{(5)-(1)}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.220	35.3	45.0	6.13	0.107	0.49	7.50	0.115	0.52
1-Q- 5	0.141	15.8	19.0	2.74	0.028	0.20	3.17	0.036	0.26
1-Q-10	0.113	6.8	12.0	1.17	0.000	0.00	2.00	0.008	0.07
1-Q-20	0.095	1.0	4.0	0.17	-0.018	-0.19	0.67	-0.010	-0.11
3-Q- 2	0.230	38.5	47.0	6.70	0.117	0.51	7.83	0.125	0.54
3-Q- 5	0.149	16.5	19.0	2.87	0.036	0.24	3.17	0.044	0.30
3-Q-10	0.120	9.5	16.0	1.65	0.007	0.06	2.67	0.015	0.13
3-Q-20	0.102	1.5	6.0	0.26	-0.011	-0.11	1.00	-0.003	-0.03
7-Q- 2	0.246	42.8	53.0	7.43	0.133	0.54	8.83	0.141	0.57
7-Q- 5	0.164	18.3	24.0	3.17	0.051	0.31	4.00	0.059	0.36
7-Q-10	0.137	12.5	19.0	2.17	0.024	0.18	3.17	0.032	0.23
7-Q-20	0.122	10.0	16.0	1.74	0.009	0.07	2.67	0.017	0.14
15-Q- 2	0.300	58.5	68.0	10.17	0.187	0.62	11.33	0.195	0.65
15-Q- 5	0.202	28.8	36.0	5.00	0.089	0.44	6.00	0.097	0.48
15-Q-10	0.159	17.0	20.0	2.96	0.046	0.29	3.33	0.054	0.34
15-Q-20	0.130	11.8	17.0	2.04	0.017	0.13	2.83	0.025	0.19
30-Q- 2	0.358	73.0	86.0	12.70	0.245	0.68	14.33	0.253	0.71
30-Q- 5	0.237	41.5	51.0	7.22	0.124	0.52	8.50	0.132	0.56
30-Q-10	0.188	25.3	31.0	4.39	0.075	0.40	5.17	0.083	0.44
30-Q-20	0.157	17.0	19.0	2.96	0.044	0.28	3.17	0.052	0.33

Table H.11 Coldwater River

Hydrometric Station Number 02ED007

Period of Record 1966 - 1986		Max. No. of Excurs. Allow. =	6.9
(1) CCC Design Flow =	0.761	(2) Number of Excursions =	6.3
(3) CMC Design Flow =	0.736	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\frac{(5)-(1)}{}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.927	28.5	43.0	4.56	0.166	0.18	7.17	0.191	0.21
1-Q- 5	0.836	15.0	19.0	2.40	0.075	0.09	3.17	0.100	0.12
1-Q-10	0.777	9.5	15.0	1.52	0.016	0.02	2.50	0.041	0.05
1-Q-20	0.721	2.0	6.0	0.32	-0.040	-0.06	1.00	-0.015	-0.02
3-Q- 2	0.941	34.0	49.0	5.44	0.180	0.19	8.17	0.205	0.22
3-Q- 5	0.849	16.3	20.0	2.60	0.088	0.10	3.33	0.113	0.13
3-Q-10	0.793	12.0	15.0	1.92	0.032	0.04	2.50	0.057	0.07
3-Q-20	0.744	6.0	7.0	0.96	-0.017	-0.02	1.17	0.008	0.01
7-Q- 2	0.963	41.5	59.0	6.64	0.202	0.21	9.83	0.227	0.24
7-Q- 5	0.873	19.3	20.0	3.08	0.112	0.13	3.33	0.137	0.16
7-Q-10	0.821	15.0	17.0	2.40	0.060	0.07	2.83	0.085	0.10
7-Q-20	0.777	9.5	15.0	1.52	0.016	0.02	2.50	0.041	0.05
15-Q- 2	1.005	62.0	85.0	9.92	0.244	0.24	14.17	0.269	0.27
15-Q- 5	0.902	20.0	24.0	3.20	0.141	0.16	4.00	0.166	0.18
15-Q-10	0.841	16.3	19.0	2.60	0.080	0.10	3.17	0.105	0.12
15-Q-20	0.788	11.3	15.0	1.80	0.027	0.03	2.50	0.052	0.07
30-Q- 2	1.089	110.0	131.0	17.60	0.328	0.30	21.83	0.353	0.32
30-Q- 5	0.976	49.3	66.0	7.88	0.215	0.22	11.00	0.240	0.25
30-Q-10	0.904	20.0	24.0	3.20	0.143	0.16	4.00	0.168	0.19
30-Q-20	0.838	16.0	19.0	2.56	0.077	0.09	3.17	0.102	0.12

Table H.12 Sauble River									
Hydrometric Station Number 02FA001									
Period of Record 1958 - 1986		Max. No. of Excurs. Allow. =	9.6						
(1) CCC Design Flow =	0.630	(2) Number of Excursions =	9.5						
(3) CMC Design Flow =	0.600	(4) Number of Excursions =	9.0						
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	1.111	55.5	68.0	5.84	0.481	0.43	7.56	0.511	0.46
1-Q- 5	0.716	18.5	26.0	1.95	0.086	0.12	2.89	0.116	0.16
1-Q-10	585	6.3	8.0	0.66	-0.045	-0.08	0.89	-0.015	-0.03
1-Q-20	0.512	5.0	5.0	0.53	-0.118	-0.23	0.56	-0.088	-0.17
3-Q- 2	1.157	60.0	71.0	6.32	0.527	0.46	7.89	0.557	0.48
3-Q- 5	0.753	20.8	27.0	2.18	0.123	0.16	3.00	0.153	0.20
3-Q-10	0.618	7.8	12.0	0.82	-0.012	-0.02	1.33	0.018	0.03
3-Q-20	0.542	5.0	6.0	0.53	-0.088	-0.16	0.67	-0.058	-0.11
7-Q- 2	1.229	70.3	81.0	7.39	0.599	0.49	9.00	0.629	0.51
7-Q- 5	0.788	24.3	28.0	2.55	0.158	0.20	3.11	0.188	0.24
7-Q-10	0.648	10.0	15.0	1.05	0.018	0.03	1.67	0.048	0.07
7-Q-20	0.571	5.0	6.0	0.53	-0.059	-0.10	0.67	-0.029	-0.05
15-Q- 2	1.328	76.0	85.0	8.00	0.698	0.53	9.44	0.728	0.55
15-Q- 5	0.838	26.0	31.0	2.74	0.208	0.25	3.44	0.238	0.28
15-Q-10	0.684	14.3	26.0	1.50	0.054	0.08	2.89	0.084	0.12
15-Q-20	0.600	6.8	9.0	0.71	-0.030	-0.05	1.00	0.000	0.00
30-Q- 2	1.552	95.0	108.0	10.00	0.922	0.59	12.00	0.952	0.61
30-Q- 5	0.965	33.0	46.0	3.47	0.335	0.35	5.11	0.365	0.38
30-Q-10	0.771	22.8	27.0	2.39	0.141	0.18	3.00	0.171	0.22
30-Q-20	0.662	12.3	20.0	1.29	0.032	0.05	2.22	0.062	0.09

Table H.13 Saugeen River

Hydrometric Station Number 02FC002

Period of Record 1915 - 1986		Max. No. of Excurs. Allow. =	23.9
(1) CCC Design Flow =	3.882	(2) Number of Excursions =	21.5
(3) CMC Design Flow =	3.479	(4) Number of Excursions =	22.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	5.538	114.8	150.0	5.34	1.656	0.30	6.82	2.059	0.37
1-Q- 5	4.019	30.3	53.0	1.41	0.137	0.03	2.41	0.540	0.13
1-Q-10	3.360	6.3	18.0	0.29	-0.522	-0.16	0.82	-0.119	-0.04
1-Q-20	2.903	0.0	6.0	0.00	-0.979	-0.34	0.27	-0.576	-0.20
3-Q- 2	6.066	162.0	219.0	7.53	2.184	0.36	9.95	2.587	0.43
3-Q- 5	4.655	61.0	87.0	2.84	0.773	0.17	3.95	1.176	0.25
3-Q-10	4.032	30.5	55.0	1.42	0.150	0.04	2.50	0.553	0.14
3-Q-20	3.594	12.3	28.0	0.57	-0.288	-0.08	1.27	0.115	0.03
7-Q- 2	6.429	189.5	241.0	8.81	2.547	0.40	10.95	2.950	0.46
7-Q- 5	5.006	78.8	109.0	3.66	1.124	0.22	4.95	1.527	0.31
7-Q-10	4.384	50.3	78.0	2.34	0.502	0.11	3.55	0.905	0.21
7-Q-20	3.951	27.3	50.0	1.27	0.069	0.02	2.27	0.472	0.12
15-Q- 2	6.782	220.0	261.0	10.23	2.900	0.43	11.86	3.303	0.49
15-Q- 5	5.233	93.0	131.0	4.33	1.351	0.26	5.95	1.754	0.34
15-Q-10	4.579	60.3	82.0	2.80	0.697	0.15	3.73	1.100	0.24
15-Q-20	4.135	35.5	63.0	1.65	0.253	0.06	2.86	0.656	0.16
30-Q- 2	7.345	270.5	329.0	12.58	3.463	0.47	14.95	3.866	0.53
30-Q- 5	5.535	114.8	150.0	5.34	1.653	0.30	6.82	2.056	0.37
30-Q-10	4.813	68.0	100.0	3.16	0.931	0.19	4.55	1.334	0.28
30-Q-20	4.345	47.3	75.0	2.20	0.463	0.11	3.41	0.866	0.20

Table H.14 Nith River

Hydrometric Station Number 02GA018

Period of Record 1951 - 1986		Max. No. of Excurs. Allow. =	11.9
(1) CCC Design Flow =	0.116	(2) Number of Excursions =	10.8
(3) CMC Design Flow =	0.085	(4) Number of Excursions =	4.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.297	68.3	78.0	6.35	0.181	0.61	19.50	0.212	0.71
1-Q- 5	0.155	22.3	31.0	2.07	0.039	0.25	7.75	0.070	0.45
1-Q-10	0.097	5.8	17.0	0.53	-0.019	-0.20	4.25	0.012	0.12
1-Q-20	0.059	2.3	4.0	0.21	-0.057	-0.97	1.00	-0.026	-0.44
3-Q- 2	0.308	69.5	80.0	6.47	0.192	0.62	20.00	0.223	0.72
3-Q- 5	0.167	24.5	31.0	2.28	0.051	0.31	7.75	0.082	0.49
3-Q-10	0.112	9.5	22.0	0.88	-0.004	-0.04	5.50	0.027	0.24
3-Q-20	0.077	3.5	4.0	0.33	-0.039	-0.51	1.00	-0.008	-0.10
7-Q- 2	0.325	76.8	90.0	7.14	0.209	0.64	22.50	0.240	0.74
7-Q- 5	0.191	28.3	37.0	2.63	0.075	0.39	9.25	0.106	0.55
7-Q-10	0.143	17.5	30.0	1.63	0.027	0.19	7.50	0.058	0.41
7-Q-20	0.113	10.5	22.0	0.98	-0.003	-0.03	5.50	0.028	0.25
15-Q- 2	0.359	110.8	125.0	10.30	0.243	0.68	31.25	0.274	0.76
15-Q- 5	0.239	47.3	55.0	4.40	0.123	0.51	13.75	0.154	0.64
15-Q-10	0.200	32.3	48.0	3.00	0.084	0.42	12.00	0.115	0.58
15-Q-20	0.178	26.8	37.0	2.49	0.062	0.35	9.25	0.093	0.52
30-Q- 2	0.432	163.8	180.0	15.23	0.316	0.73	45.00	0.347	0.80
30-Q- 5	0.287	63.8	76.0	5.93	0.171	0.60	19.00	0.202	0.70
30-Q-10	0.236	47.0	55.0	4.37	0.120	0.51	13.75	0.151	0.64
30-Q-20	0.207	35.5	49.0	3.30	0.091	0.44	12.25	0.122	0.59

Table H.15 Fairchild Creek

Hydrometric Station Number 02GB007

Period of Record 1965 - 1986		Max. No. of Excurs. Allow. =	7.2						
(1) CCC Design Flow =	0.077	(2) Number of Excursions =	7.0						
(3) CMC Design Flow =	0.057	(4) Number of Excursions =	7.0						
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.288	51.0	67.0	7.29	0.211	0.73	9.57	0.231	0.80
1-Q- 5	0.137	10.0	10.0	1.43	0.060	0.44	1.43	0.080	0.58
1-Q-10	0.085	8.5	10.0	1.21	0.008	0.09	1.43	0.028	0.33
1-Q-20	0.056	3.5	7.0	0.50	-0.021	-0.37	1.00	-0.001	-0.02
3-Q- 2	0.298	56.3	67.0	8.04	0.221	0.74	9.57	0.241	0.81
3-Q- 5	0.149	10.0	10.0	1.43	0.072	0.48	1.43	0.092	0.62
3-Q-10	0.098	10.0	10.0	1.43	0.021	0.21	1.43	0.041	0.42
3-Q-20	0.068	5.8	8.0	0.82	-0.009	-0.13	1.14	0.011	0.16
7-Q- 2	0.316	63.0	70.0	9.00	0.239	0.76	10.00	0.259	0.82
7-Q- 5	0.167	10.0	11.0	1.43	0.090	0.54	1.57	0.110	0.66
7-Q-10	0.114	10.0	10.0	1.43	0.037	0.32	1.43	0.057	0.50
7-Q-20	0.084	8.0	10.0	1.14	0.007	0.08	1.43	0.027	0.32
15-Q- 2	0.346	80.0	85.0	11.43	0.269	0.78	12.14	0.289	0.84
15-Q- 5	0.202	21.0	22.0	3.00	0.125	0.62	3.14	0.145	0.72
15-Q-10	0.154	10.0	10.0	1.43	0.077	0.50	1.43	0.097	0.63
15-Q-20	0.126	10.0	10.0	1.43	0.049	0.39	1.43	0.069	0.55
30-Q- 2	0.379	85.5	92.0	12.21	0.302	0.80	13.14	0.322	0.85
30-Q- 5	0.246	29.8	40.0	4.25	0.169	0.69	5.71	0.189	0.77
30-Q-10	0.207	21.0	22.0	3.00	0.130	0.63	3.14	0.150	0.72
30-Q-20	0.186	12.0	20.0	1.71	0.109	0.59	2.86	0.129	0.69

Table H.16 Big Otter Creek										
Hydrometric Station Number 02GC010										
Period of Record 1961 - 1986		Max. No. of Excurs. Allow. =	8.6							
(1) CCC Design Flow =	0.323	(2) Number of Excursions =	7.8							
(3) CMC Design Flow =	0.258	(4) Number of Excursions =	8.0							
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\underline{(5)-(1)}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.455	28.0	56.0	3.61	0.132	0.29	7.00	0.197	0.43
1-Q- 5	0.253	6.0	8.0	0.77	-0.070	-0.28	1.00	-0.005	-0.02
1-Q-10	0.179	1.5	5.0	0.19	-0.144	-0.80	0.63	-0.079	-0.44
1-Q-20	0.134	0.0	4.0	0.00	-0.189	-1.41	0.50	-0.124	-0.93
3-Q- 2	0.508	40.3	71.0	5.19	0.185	0.36	8.88	0.250	0.49
3-Q- 5	0.322	7.8	18.0	1.00	-0.001	-0.00	2.25	0.064	0.20
3-Q-10	0.261	6.5	9.0	0.84	-0.062	-0.24	1.13	0.003	0.01
3-Q-20	0.226	4.5	7.0	0.58	-0.097	-0.43	0.88	-0.032	-0.14
7-Q- 2	0.564	46.5	75.0	6.00	0.241	0.43	9.38	0.306	0.54
7-Q- 5	0.393	17.5	40.0	2.26	0.070	0.18	5.00	0.135	0.34
7-Q-10	0.339	11.3	27.0	1.45	0.016	0.05	3.38	0.081	0.24
7-Q-20	0.310	7.5	15.0	0.97	-0.013	-0.04	1.88	0.052	0.17
15-Q- 2	0.667	63.8	99.0	8.23	0.344	0.52	12.38	0.409	0.61
15-Q- 5	0.504	38.3	70.0	4.94	0.181	0.36	8.75	0.246	0.49
15-Q-10	0.455	28.0	56.0	3.61	0.132	0.29	7.00	0.197	0.43
15-Q-20	0.430	24.8	49.0	3.19	0.107	0.25	6.13	0.172	0.40
30-Q- 2	0.875	121.3	134.0	15.65	0.552	0.63	16.75	0.617	0.71
30-Q- 5	0.683	69.0	103.0	8.90	0.360	0.53	12.88	0.425	0.62
30-Q-10	0.603	50.0	78.0	6.45	0.280	0.46	9.75	0.345	0.57
30-Q-20	0.551	45.8	74.0	5.90	0.228	0.41	9.25	0.293	0.53

Table H.17 Catfish Creek

Hydrometric Station Number 02GC018

Period of Record 1965 - 1986		Max. No. of Excurs. Allow. =	7.2
(1) CCC Design Flow =	0.052	(2) Number of Excursions =	6.8
(3) CMC Design Flow =	0.042	(4) Number of Excursions =	7.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\frac{(5)-(1)}{}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.134	47.8	58.0	7.07	0.082	0.61	8.29	0.092	0.69
1-Q- 5	0.081	14.3	21.0	2.11	0.029	0.36	3.00	0.039	0.48
1-Q-10	0.055	9.3	14.0	1.37	0.003	0.05	2.00	0.013	0.24
1-Q-20	0.035	1.3	4.0	0.19	-0.017	-0.49	0.57	-0.007	-0.20
3-Q- 2	0.138	51.3	60.0	7.59	0.086	0.62	8.57	0.096	0.70
3-Q- 5	0.084	15.0	22.0	2.22	0.032	0.38	3.14	0.042	0.50
3-Q-10	0.060	12.5	17.0	1.85	0.008	0.13	2.43	0.018	0.30
3-Q-20	0.042	2.3	7.0	0.33	-0.010	-0.24	1.00	0.000	0.00
7-Q- 2	0.147	55.3	63.0	8.19	0.095	0.65	9.00	0.105	0.71
7-Q- 5	0.090	16.3	22.0	2.41	0.038	0.42	3.14	0.048	0.53
7-Q-10	0.067	13.5	17.0	2.00	0.015	0.22	2.43	0.025	0.37
7-Q-20	0.052	6.8	14.0	1.00	0.000	0.00	2.00	0.010	0.19
15-Q- 2	0.173	69.5	77.0	10.30	0.121	0.70	11.00	0.131	0.76
15-Q- 5	0.111	25.5	35.0	3.78	0.059	0.53	5.00	0.069	0.62
15-Q-10	0.088	16.0	22.0	2.37	0.036	0.41	3.14	0.046	0.52
15-Q-20	0.073	14.0	20.0	2.07	0.021	0.29	2.86	0.031	0.42
30-Q- 2	0.205	85.5	100.0	12.67	0.153	0.75	14.29	0.163	0.80
30-Q- 5	0.108	23.5	31.0	3.48	0.056	0.52	4.43	0.066	0.61
30-Q-10	0.084	15.0	22.0	2.22	0.032	0.38	3.14	0.042	0.50
30-Q-20	0.072	14.0	20.0	2.07	0.020	0.28	2.86	0.030	0.42

Table H.18 Grindstone Creek									
Hydrometric Station Number 02HB012									
Period of Record 1966 - 1986		Max. No. of Excurs. Allow. = 6.9							
(1) CCC Design Flow = 0.040		(2) Number of Excursions = 6.0							
(3) CMC Design Flow = 0.031		(4) Number of Excursions = 4.0							
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.053	23.3	38.0	3.88	0.013	0.25	9.50	0.022	0.42
1-Q- 5	0.040	6.0	9.0	1.00	0.000	0.00	2.25	0.009	0.23
1-Q-10	0.034	2.8	7.0	0.46	-0.006	-0.18	1.75	0.003	0.09
1-Q-20	0.030	0.0	3.0	0.00	-0.010	-0.33	0.75	-0.001	-0.03
3-Q- 2	0.059	36.5	51.0	6.08	0.019	0.32	12.75	0.028	0.47
3-Q- 5	0.045	12.5	23.0	2.08	0.005	0.11	5.75	0.014	0.31
3-Q-10	0.039	6.0	9.0	1.00	-0.001	-0.03	2.25	0.008	0.21
3-Q-20	0.035	3.0	9.0	0.50	-0.005	-0.14	2.25	0.004	0.11
7-Q- 2	0.066	52.0	63.0	8.67	0.026	0.39	15.75	0.035	0.53
7-Q- 5	0.052	22.0	37.0	3.67	0.012	0.23	9.25	0.021	0.40
7-Q-10	0.045	12.5	23.0	2.08	0.005	0.11	5.75	0.014	0.31
7-Q-20	0.041	8.3	15.0	1.38	0.001	0.02	3.75	0.010	0.24
15-Q- 2	0.074	67.8	85.0	11.29	0.034	0.46	21.25	0.043	0.58
15-Q- 5	0.056	28.3	45.0	4.71	0.016	0.29	11.25	0.025	0.45
15-Q-10	0.049	16.5	33.0	2.75	0.009	0.18	8.25	0.018	0.37
15-Q-20	0.044	11.0	22.0	1.83	0.004	0.09	5.50	0.013	0.30
30-Q- 2	0.088	89.5	99.0	14.92	0.048	0.55	24.75	0.057	0.65
30-Q- 5	0.066	52.0	63.0	8.67	0.026	0.39	15.75	0.035	0.53
30-Q-10	0.057	29.5	46.0	4.92	0.017	0.30	11.50	0.026	0.46
30-Q-20	0.051	21.0	33.0	3.50	0.011	0.22	8.25	0.020	0.39

Table H.19 East Humber River

Hydrometric Station Number 02HC009

Period of Record 1954 - 1986		Max. No. of Excurs. Allow. =	10.9
(1) CCC Design Flow =	0.078	(2) Number of Excursions =	10.8
(3) CMC Design Flow =	0.057	(4) Number of Excursions =	4.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\frac{(5)-(1)}{}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.135	49.5	70.0	4.60	0.057	0.42	17.50	0.078	0.58
1-Q- 5	0.079	12.0	19.0	1.12	0.001	0.01	4.75	0.022	0.28
1-Q-10	0.053	3.3	4.0	0.30	-0.025	-0.47	1.00	-0.004	-0.08
1-Q-20	0.034	1.8	2.0	0.16	-0.044	-1.29	0.50	-0.023	-0.68
3-Q- 2	0.144	76.0	103.0	7.07	0.066	0.46	25.75	0.087	0.60
3-Q- 5	0.098	27.8	41.0	2.58	0.020	0.20	10.25	0.041	0.42
3-Q-10	0.081	13.0	23.0	1.21	0.003	0.04	5.75	0.024	0.30
3-Q-20	0.070	7.8	16.0	0.72	-0.008	-0.11	4.00	0.013	0.19
7-Q- 2	0.157	94.5	111.0	8.79	0.079	0.50	27.75	0.100	0.64
7-Q- 5	0.109	35.5	41.0	3.30	0.031	0.28	10.25	0.052	0.48
7-Q-10	0.091	24.3	35.0	2.26	0.013	0.14	8.75	0.034	0.37
7-Q-20	0.080	12.0	23.0	1.12	0.002	0.03	5.75	0.023	0.29
15-Q- 2	0.170	115.8	133.0	10.77	0.092	0.54	33.25	0.113	0.66
15-Q- 5	0.123	41.0	52.0	3.81	0.045	0.37	13.00	0.066	0.54
15-Q-10	0.107	34.5	41.0	3.21	0.029	0.27	10.25	0.050	0.47
15-Q-20	0.098	27.8	41.0	2.58	0.020	0.20	10.25	0.041	0.42
30-Q- 2	0.198	172.5	193.0	16.05	0.120	0.61	48.25	0.141	0.71
30-Q- 5	0.147	84.8	103.0	7.88	0.069	0.47	25.75	0.090	0.61
30-Q-10	0.130	46.5	60.0	4.33	0.052	0.40	15.00	0.073	0.56
30-Q-20	0.120	41.0	51.0	3.81	0.042	0.35	12.75	0.063	0.53

Table H.20 Highland Creek										
Hydrometric Station Number 02HC013										
Period of Record 1958 - 1986		Max. No. of Excurs. Allow. = 8.9								
(1) CCC Design Flow = 0.085		(2) Number of Excursions = 3.5								
(3) CMC Design Flow = 0.085		(4) Number of Excursions = 5.0								
Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.202	87.5	114.0	25.00	0.117	0.58	22.80	0.117	0.58
1-Q- 5	0.126	17.0	25.0	4.86	0.041	0.33	5.00	0.041	0.33
1-Q-10	0.090	9.0	16.0	2.57	0.005	0.06	3.20	0.005	0.06
1-Q-20	0.064	3.0	5.0	0.86	-0.021	-0.33	1.00	-0.021	-0.33
3-Q- 2	0.214	101.3	121.0	28.93	0.129	0.60	24.20	0.129	0.60
3-Q- 5	0.134	20.0	28.0	5.71	0.049	0.37	5.60	0.049	0.37
3-Q-10	0.095	9.8	16.0	2.79	0.010	0.11	3.20	0.010	0.11
3-Q-20	0.067	3.0	5.0	0.86	-0.018	-0.27	1.00	-0.018	-0.27
7-Q- 2	0.233	130.0	157.0	37.14	0.148	0.64	31.40	0.148	0.64
7-Q- 5	0.148	27.0	42.0	7.71	0.063	0.43	8.40	0.063	0.43
7-Q-10	0.106	11.3	18.0	3.21	0.021	0.20	3.60	0.021	0.20
7-Q-20	0.075	3.3	5.0	0.93	-0.010	-0.13	1.00	-0.010	-0.13
15-Q- 2	0.270	170.3	182.0	48.64	0.185	0.69	36.40	0.185	0.69
15-Q- 5	0.181	50.8	81.0	14.50	0.096	0.53	16.20	0.096	0.53
15-Q-10	0.136	20.3	29.0	5.79	0.051	0.38	5.80	0.051	0.38
15-Q-20	0.102	11.3	18.0	3.21	0.017	0.17	3.60	0.017	0.17
30-Q- 2	0.314	226.0	246.0	64.57	0.229	0.73	49.20	0.229	0.73
30-Q- 5	0.199	81.5	111.0	23.29	0.114	0.57	22.20	0.114	0.57
30-Q-10	0.153	30.0	43.0	8.57	0.068	0.44	8.60	0.068	0.44
30-Q-20	0.122	15.5	23.0	4.43	0.037	0.30	4.60	0.037	0.30

Table H.21 Lynde Creek

Hydrometric Station Number 02HC018

Period of Record 1961 - 1986		Max. No. of Excurs. Allow. =	7.2
(1) CCC Design Flow =	0.040	(2) Number of Excursions =	7.0
(3) CMC Design Flow =	0.028	(4) Number of Excursions =	2.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.084	33.3	44.0	4.75	0.044	0.52	22.00	0.056	0.67
1-Q- 5	0.053	8.0	11.0	1.14	0.013	0.25	5.50	0.025	0.47
1-Q-10	0.041	7.5	10.0	1.07	0.001	0.02	5.00	0.013	0.32
1-Q-20	0.032	2.8	10.0	0.39	-0.008	-0.25	5.00	0.004	0.13
3-Q- 2	0.092	41.0	51.0	5.86	0.052	0.57	25.50	0.064	0.70
3-Q- 5	0.060	8.0	17.0	1.14	0.020	0.33	8.50	0.032	0.53
3-Q-10	0.047	7.8	10.0	1.11	0.007	0.15	5.00	0.019	0.40
3-Q-20	0.037	5.3	10.0	0.75	-0.003	-0.08	5.00	0.009	0.24
7-Q- 2	0.104	44.0	62.0	6.29	0.064	0.62	31.00	0.076	0.73
7-Q- 5	0.069	12.5	25.0	1.79	0.029	0.42	12.50	0.041	0.59
7-Q-10	0.053	8.0	11.0	1.14	0.013	0.25	5.50	0.025	0.47
7-Q-20	0.042	7.8	10.0	1.11	0.002	0.05	5.00	0.014	0.33
15-Q- 2	0.125	78.8	89.0	11.25	0.085	0.68	44.50	0.097	0.78
15-Q- 5	0.087	37.3	50.0	5.32	0.047	0.54	25.00	0.059	0.68
15-Q-10	0.070	12.5	26.0	1.79	0.030	0.43	13.00	0.042	0.60
15-Q-20	0.058	8.0	16.0	1.14	0.018	0.31	8.00	0.030	0.52
30-Q- 2	0.154	117.3	133.0	16.75	0.114	0.74	66.50	0.126	0.82
30-Q- 5	0.100	43.3	58.0	6.18	0.060	0.60	29.00	0.072	0.72
30-Q-10	0.080	28.8	44.0	4.11	0.040	0.50	22.00	0.052	0.65
30-Q-20	0.067	11.8	21.0	1.68	0.027	0.40	10.50	0.039	0.58

Table H.22 Don River @ Bayview Exit

Hydrometric Station Number 02HC024

Period of Record 1963 - 1986		Max. No. of Excurs. Allow. =	7.9
(1) CCC Design Flow =	1.134	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	1.099	(4) Number of Excursions =	7.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	1.305	27.5	49.0	4.58	0.171	0.13	7.00	0.206	0.16
1-Q- 5	1.203	15.8	22.0	2.63	0.069	0.06	3.14	0.104	0.09
1-Q-10	1.136	6.0	15.0	1.00	0.002	0.00	2.14	0.037	0.03
1-Q-20	1.071	1.8	7.0	0.29	-0.063	-0.06	1.00	-0.028	-0.03
3-Q- 2	1.345	39.5	76.0	6.58	0.211	0.16	10.86	0.246	0.18
3-Q- 5	1.235	16.5	23.0	2.75	0.101	0.08	3.29	0.136	0.11
3-Q-10	1.165	11.8	17.0	1.96	0.031	0.03	2.43	0.066	0.06
3-Q-20	1.101	5.0	15.0	0.83	-0.033	-0.03	2.14	0.002	0.00
7-Q- 2	1.387	65.3	105.0	10.88	0.253	0.18	15.00	0.288	0.21
7-Q- 5	1.277	22.5	38.0	3.75	0.143	0.11	5.43	0.178	0.14
7-Q-10	1.214	16.3	23.0	2.71	0.080	0.07	3.29	0.115	0.09
7-Q-20	1.162	10.3	17.0	1.71	0.028	0.02	2.43	0.063	0.05
15-Q- 2	1.518	147.0	178.0	24.50	0.384	0.25	25.43	0.419	0.28
15-Q- 5	1.373	56.5	98.0	9.42	0.239	0.17	14.00	0.274	0.20
15-Q-10	1.289	24.8	39.0	4.13	0.155	0.12	5.57	0.190	0.15
15-Q-20	1.214	16.3	23.0	2.71	0.080	0.07	3.29	0.115	0.09
30-Q- 2	1.711	233.0	317.6	38.83	0.577	0.34	45.37	0.612	0.36
30-Q- 5	1.475	121.0	156.0	20.17	0.341	0.23	22.29	0.376	0.25
30-Q-10	1.368	56.0	92.0	9.33	0.234	0.17	13.14	0.269	0.20
30-Q-20	1.291	24.8	42.0	4.13	0.157	0.12	6.00	0.192	0.15

Table H.23 Humber River

Hydrometric Station Number 02HC025

Period of Record 1963 - 1986		Max. No. of Excurs. Allow. =	7.9
(1) CCC Design Flow =	0.619	(2) Number of Excursions =	7.0
(3) CMC Design Flow =	0.573	(4) Number of Excursions =	7.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.722	26.5	41.0	3.79	0.103	0.14	5.86	0.149	0.21
1-Q- 5	0.606	4.8	15.0	0.68	-0.013	-0.02	2.14	0.033	0.05
1-Q-10	0.557	2.8	7.0	0.39	-0.062	-0.11	1.00	-0.016	-0.03
1-Q-20	0.524	0.0	1.0	0.00	-0.095	-0.18	0.14	-0.049	-0.09
3-Q- 2	0.766	37.0	58.0	5.29	0.147	0.19	8.29	0.193	0.25
3-Q- 5	0.653	17.8	31.0	2.54	0.034	0.05	4.43	0.080	0.12
3-Q-10	0.602	4.8	14.0	0.68	-0.017	-0.03	2.00	0.029	0.05
3-Q-20	0.565	2.8	7.0	0.39	-0.054	-0.10	1.00	-0.008	-0.01
7-Q- 2	0.820	51.5	77.0	7.36	0.201	0.25	11.00	0.247	0.30
7-Q- 5	0.701	24.3	37.0	3.46	0.082	0.12	5.29	0.128	0.18
7-Q-10	0.640	12.3	27.0	1.75	0.021	0.03	3.86	0.067	0.10
7-Q-20	0.591	3.5	13.0	0.50	-0.028	-0.05	1.86	0.018	0.03
15-Q- 2	0.898	91.0	120.0	13.00	0.279	0.31	17.14	0.325	0.36
15-Q- 5	0.763	36.0	55.0	5.14	0.144	0.19	7.86	0.190	0.25
15-Q-10	0.687	22.8	34.0	3.25	0.068	0.10	4.86	0.114	0.17
15-Q-20	0.621	8.3	21.0	1.18	0.002	0.00	3.00	0.048	0.08
30-Q- 2	1.014	155.0	180.0	22.14	0.395	0.39	25.71	0.441	0.43
30-Q- 5	0.857	67.8	93.0	9.68	0.238	0.28	13.29	0.284	0.33
30-Q-10	0.777	37.8	61.0	5.39	0.158	0.20	8.71	0.204	0.26
30-Q-20	0.713	26.3	39.0	3.75	0.094	0.13	5.57	0.140	0.20

Table H.24 Etobicoke Creek

Hydrometric Station Number 02HC030

Period of Record 1967 - 1986		Max. No. of Excurs. Allow. =	6.6
(1) CCC Design Flow =	0.160	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	0.127	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.186	24.0	53.0	4.00	0.026	0.14	8.83	0.059	0.32
1-Q- 5	0.144	3.8	9.0	0.63	-0.016	-0.11	1.50	0.017	0.12
1-Q-10	0.128	1.8	7.0	0.29	-0.032	-0.25	1.17	0.001	0.01
1-Q-20	0.119	1.3	1.0	0.21	-0.041	-0.34	0.17	-0.008	-0.07
3-Q- 2	0.202	38.8	60.0	6.46	0.042	0.21	10.00	0.075	0.37
3-Q- 5	0.157	5.8	16.0	0.96	-0.003	-0.02	2.67	0.030	0.19
3-Q-10	0.140	3.5	8.0	0.58	-0.020	-0.14	1.33	0.013	0.09
3-Q-20	0.129	2.0	7.0	0.33	-0.031	-0.24	1.17	0.002	0.02
7-Q- 2	0.228	60.0	80.0	10.00	0.068	0.30	13.33	0.101	0.44
7-Q- 5	0.176	17.5	36.0	2.92	0.016	0.09	6.00	0.049	0.28
7-Q-10	0.156	5.8	13.0	0.96	-0.004	-0.03	2.17	0.029	0.19
7-Q-20	0.142	3.5	8.0	0.58	-0.018	-0.13	1.33	0.015	0.11
15-Q- 2	0.261	84.5	117.0	14.08	0.101	0.39	19.50	0.134	0.51
15-Q- 5	0.205	41.0	61.0	6.83	0.045	0.22	10.17	0.078	0.38
15-Q-10	0.188	26.8	54.0	4.46	0.028	0.15	9.00	0.061	0.32
15-Q-20	0.179	20.0	45.0	3.33	0.019	0.11	7.50	0.052	0.29
30-Q- 2	0.337	147.0	170.0	24.50	0.177	0.53	28.33	0.210	0.62
30-Q- 5	0.243	67.5	90.0	11.25	0.083	0.34	15.00	0.116	0.48
30-Q-10	0.216	49.0	72.0	8.17	0.056	0.26	12.00	0.089	0.41
30-Q-20	0.202	38.8	60.0	6.46	0.042	0.21	10.00	0.075	0.37

Table H.25 Mimico Creek

Hydrometric Station Number 02HC033

Period of Record 1966 - 1986		Max. No. of Excurs. Allow. =	6.7
(1) CCC Design Flow =	0.055	(2) Number of Excursions =	5.3
(3) CMC Design Flow =	0.048	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.073	23.5	52.0	4.48	0.018	0.25	8.67	0.025	0.34
1-Q- 5	0.054	4.0	14.0	0.76	-0.001	-0.02	2.33	0.006	0.11
1-Q-10	0.046	2.0	6.0	0.38	-0.009	-0.20	1.00	-0.002	-0.04
1-Q-20	0.041	1.8	5.0	0.33	-0.014	-0.34	0.83	-0.007	-0.17
3-Q- 2	0.081	36.0	66.0	6.86	0.026	0.32	11.00	0.033	0.41
3-Q- 5	0.055	7.3	17.0	1.38	0.000	0.00	2.83	0.007	0.13
3-Q-10	0.047	2.0	6.0	0.38	-0.008	-0.17	1.00	-0.001	-0.02
3-Q-20	0.042	1.8	5.0	0.33	-0.013	-0.31	0.83	-0.006	-0.14
7-Q- 2	0.096	73.3	101.0	13.95	0.041	0.43	16.83	0.048	0.50
7-Q- 5	0.060	9.5	20.0	1.81	0.005	0.08	3.33	0.012	0.20
7-Q-10	0.050	2.3	9.0	0.43	-0.005	-0.10	1.50	0.002	0.04
7-Q-20	0.045	2.0	5.0	0.38	-0.010	-0.22	0.83	-0.003	-0.07
15-Q- 2	0.085	43.3	74.0	8.24	0.030	0.35	12.33	0.037	0.44
15-Q- 5	0.060	9.5	20.0	1.81	0.005	0.08	3.33	0.012	0.20
15-Q-10	0.057	8.8	17.0	1.67	0.002	0.04	2.83	0.009	0.16
15-Q-20	0.057	8.8	17.0	1.67	0.002	0.04	2.83	0.009	0.16
30-Q- 2	0.164	245.3	260.0	46.71	0.109	0.66	43.33	0.116	0.71
30-Q- 5	0.119	125.8	164.0	23.95	0.064	0.54	27.33	0.071	0.60
30-Q-10	0.097	74.5	107.0	14.19	0.042	0.43	17.83	0.049	0.51
30-Q-20	0.081	36.0	66.0	6.86	0.026	0.32	11.00	0.033	0.41

Table H.26 Wilmot Creek

Hydrometric Station Number 02HD009

Period of Record 1966 - 1986

Max. No. of Excurs. Allow. = 6.9

(1) CCC Design Flow = 0.251

(2) Number of Excursions = 6.8

(3) CMC Design Flow = 0.210

(4) Number of Excursions = 6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	(5)-(1) (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.317	33.3	45.0	4.93	0.066	0.21	7.50	0.107	0.34
1-Q- 5	0.254	7.0	12.0	1.04	0.003	0.01	2.00	0.044	0.17
1-Q-10	0.221	4.0	10.0	0.59	-0.030	-0.14	1.67	0.011	0.05
1-Q-20	0.195	0.0	4.0	0.00	-0.056	-0.29	0.67	-0.015	-0.08
3-Q- 2	0.326	39.8	55.0	5.89	0.075	0.23	9.17	0.116	0.36
3-Q- 5	0.265	8.0	14.0	1.19	0.014	0.05	2.33	0.055	0.21
3-Q-10	0.235	5.3	12.0	0.78	-0.016	-0.07	2.00	0.025	0.11
3-Q-20	0.212	3.5	7.0	0.52	-0.039	-0.18	1.17	0.002	0.01
7-Q- 2	0.341	52.3	73.0	7.74	0.090	0.26	12.17	0.131	0.38
7-Q- 5	0.279	10.8	24.0	1.59	0.028	0.10	4.00	0.069	0.25
7-Q-10	0.250	6.8	12.0	1.00	-0.001	-0.00	2.00	0.040	0.16
7-Q-20	0.228	5.0	12.0	0.74	-0.023	-0.10	2.00	0.018	0.08
15-Q- 2	0.357	66.3	88.0	9.81	0.106	0.30	14.67	0.147	0.41
15-Q- 5	0.299	25.8	34.0	3.81	0.048	0.16	5.67	0.089	0.30
15-Q-10	0.274	9.5	23.0	1.41	0.023	0.08	3.83	0.064	0.23
15-Q-20	0.258	7.0	13.0	1.04	0.007	0.03	2.17	0.048	0.19
30-Q- 2	0.381	90.5	103.0	13.41	0.130	0.34	17.17	0.171	0.45
30-Q- 5	0.334	44.5	65.0	6.59	0.083	0.25	10.83	0.124	0.37
30-Q-10	0.317	33.3	45.0	4.93	0.066	0.21	7.50	0.107	0.34
30-Q-20	0.307	31.0	36.0	4.59	0.056	0.18	6.00	0.097	0.32

Table H.27 Shelter Valley Brook

Hydrometric Station Number 02HD010

Period of Record 1966 - 1986		Max. No. of Excurs. Allow. =	6.9
(1) CCC Design Flow =	0.209	(2) Number of Excursions =	6.8
(3) CMC Design Flow =	0.205	(4) Number of Excursions =	6.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	$\frac{(6)}{(2)}$	$\frac{(5)-(1)}{}$ (m^3/s)	$\frac{(5)-(1)}{(5)}$	$\frac{(7)}{(4)}$	(5)-(3) (m^3/s)	$\frac{(5)-(3)}{(5)}$
1-Q- 2	0.292	29.8	41.0	4.41	0.083	0.28	6.83	0.087	0.30
1-Q- 5	0.236	11.3	18.0	1.67	0.027	0.11	3.00	0.031	0.13
1-Q-10	0.203	5.0	6.0	0.74	-0.006	-0.03	1.00	-0.002	-0.01
1-Q-20	0.173	3.8	5.0	0.56	-0.036	-0.21	0.83	-0.032	-0.18
3-Q- 2	0.303	42.8	54.0	6.33	0.094	0.31	9.00	0.098	0.32
3-Q- 5	0.250	16.3	22.0	2.41	0.041	0.16	3.67	0.045	0.18
3-Q-10	0.217	9.0	11.0	1.33	0.008	0.04	1.83	0.012	0.06
3-Q-20	0.187	4.5	5.0	0.67	-0.022	-0.12	0.83	-0.018	-0.10
7-Q- 2	0.316	50.3	67.0	7.44	0.107	0.34	11.17	0.111	0.35
7-Q- 5	0.262	18.5	22.0	2.74	0.053	0.20	3.67	0.057	0.22
7-Q-10	0.228	10.0	13.0	1.48	0.019	0.08	2.17	0.023	0.10
7-Q-20	0.195	5.0	6.0	0.74	-0.014	-0.07	1.00	-0.010	-0.05
15-Q- 2	0.330	63.8	83.0	9.44	0.121	0.37	13.83	0.125	0.38
15-Q- 5	0.271	19.0	24.0	2.81	0.062	0.23	4.00	0.066	0.24
15-Q-10	0.235	11.3	15.0	1.67	0.026	0.11	2.50	0.030	0.13
15-Q-20	0.201	5.0	6.0	0.74	-0.008	-0.04	1.00	-0.004	-0.02
30-Q- 2	0.354	83.3	106.0	12.33	0.145	0.41	17.67	0.149	0.42
30-Q- 5	0.290	27.5	41.0	4.07	0.081	0.28	6.83	0.085	0.29
30-Q-10	0.255	18.0	22.0	2.67	0.046	0.18	3.67	0.050	0.20
30-Q-20	0.226	10.0	12.0	1.48	0.017	0.08	2.00	0.021	0.09

Table H.28 Jackson Creek

Hydrometric Station Number 02HJ001

Period of Record 1963 - 1986		Max. No. of Excurs. Allow. =	7.9
(1) CCC Design Flow =	0.025	(2) Number of Excursions =	6.0
(3) CMC Design Flow =	0.023	(4) Number of Excursions =	5.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.064	38.3	52.0	6.38	0.039	0.61	10.40	0.041	0.64
1-Q- 5	0.037	22.3	25.0	3.71	0.012	0.32	5.00	0.014	0.38
1-Q-10	0.026	9.8	15.0	1.63	0.001	0.04	3.00	0.003	0.12
1-Q-20	0.018	1.8	5.0	0.29	-0.007	-0.39	1.00	-0.005	-0.28
3-Q- 2	0.068	44.8	53.0	7.46	0.043	0.63	10.60	0.045	0.66
3-Q- 5	0.040	23.3	25.0	3.88	0.015	0.38	5.00	0.017	0.43
3-Q-10	0.028	15.5	20.0	2.58	0.003	0.11	4.00	0.005	0.18
3-Q-20	0.020	2.0	5.0	0.33	-0.005	-0.25	1.00	-0.003	-0.15
7-Q- 2	0.076	59.8	65.0	9.96	0.051	0.67	13.00	0.053	0.70
7-Q- 5	0.045	27.8	30.0	4.63	0.020	0.44	6.00	0.022	0.49
7-Q-10	0.033	19.3	20.0	3.21	0.008	0.24	4.00	0.010	0.30
7-Q-20	0.025	6.0	11.0	1.00	0.000	0.00	2.20	0.002	0.08
15-Q- 2	0.092	87.0	104.0	14.50	0.067	0.73	20.80	0.069	0.75
15-Q- 5	0.054	30.0	33.0	5.00	0.029	0.54	6.60	0.031	0.57
15-Q-10	0.039	23.0	25.0	3.83	0.014	0.36	5.00	0.016	0.41
15-Q-20	0.030	17.5	20.0	2.92	0.005	0.17	4.00	0.007	0.23
30-Q- 2	0.118	124.5	148.0	20.75	0.093	0.79	29.60	0.095	0.81
30-Q- 5	0.071	46.8	57.0	7.79	0.046	0.65	11.40	0.048	0.68
30-Q-10	0.048	30.0	30.0	5.00	0.023	0.48	6.00	0.025	0.52
30-Q-20	0.032	19.0	20.0	3.17	0.007	0.22	4.00	0.009	0.28

Table H.29 Skootamatta River

Hydrometric Station Number 02HL004

Period of Record 1956 - 1986		Max. No. of Excurs. Allow. =	9.6
(1) CCC Design Flow =	0.027	(2) Number of Excursions =	9.5
(3) CMC Design Flow =	0.023	(4) Number of Excursions =	9.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.288	88.3	101.0	9.29	0.261	0.91	11.22	0.265	0.92
1-Q- 5	0.126	40.3	47.0	4.24	0.099	0.79	5.22	0.103	0.82
1-Q-10	0.075	29.5	27.0	3.11	0.048	0.64	3.00	0.052	0.69
1-Q-20	0.048	15.0	15.0	1.58	0.021	0.44	1.67	0.025	0.52
3-Q- 2	0.328	93.3	105.0	9.82	0.301	0.92	11.67	0.305	0.93
3-Q- 5	0.147	45.0	51.0	4.74	0.120	0.82	5.67	0.124	0.84
3-Q-10	0.088	34.8	31.0	3.66	0.061	0.69	3.44	0.065	0.74
3-Q-20	0.056	15.0	15.0	1.58	0.029	0.52	1.67	0.033	0.59
7-Q- 2	0.357	92.0	100.0	9.68	0.330	0.92	11.11	0.334	0.94
7-Q- 5	0.164	47.8	55.0	5.03	0.137	0.84	6.11	0.141	0.86
7-Q-10	0.100	35.0	37.0	3.68	0.073	0.73	4.11	0.077	0.77
7-Q-20	0.064	16.0	21.0	1.68	0.037	0.58	2.33	0.041	0.64
15-Q- 2	0.413	103.0	128.0	10.84	0.386	0.93	14.22	0.390	0.94
15-Q- 5	0.193	57.5	72.0	6.05	0.166	0.86	8.00	0.170	0.88
15-Q-10	0.118	39.3	45.0	4.13	0.091	0.77	5.00	0.095	0.81
15-Q-20	0.075	29.5	27.0	3.11	0.048	0.64	3.00	0.052	0.69
30-Q- 2	0.501	123.3	137.0	12.97	0.474	0.95	15.22	0.478	0.95
30-Q- 5	0.237	80.0	89.0	8.42	0.210	0.89	9.89	0.214	0.90
30-Q-10	0.152	45.5	51.0	4.79	0.125	0.82	5.67	0.129	0.85
30-Q-20	0.105	35.0	37.0	3.68	0.078	0.74	4.11	0.082	0.78

Table H.30 Moira River @ Hwy. 7

Hydrometric Station Number 02HL005

Period of Record 1966 - 1986		Max. No. of Excurs. Allow. =	6.9
(1) CCC Design Flow =	0.009	(2) Number of Excursions =	5.8
(3) CMC Design Flow =	0.008	(4) Number of Excursions =	4.0

Hydrologic Design Flow Parameters	(5) Hydrologic Design Flow (m^3/s)	(6) # of Excurs. with (5) as CCC Design Flow	(7) # of Excurs. with (5) as CMC Design Flow	(6) (2)	(5)-(1) (m^3/s)	(5)-(1) (5)	(7) (4)	(5)-(3) (m^3/s)	(5)-(3) (5)
1-Q- 2	0.033	40.5	45.0	7.04	0.024	0.73	11.25	0.025	0.76
1-Q- 5	0.013	16.5	23.0	2.87	0.004	0.31	5.75	0.005	0.38
1-Q-10	0.009	5.8	11.0	1.00	0.000	0.00	2.75	0.001	0.11
1-Q-20	0.007	0.0	0.0	0.00	-0.002	-0.29	0.00	-0.001	-0.14
3-Q- 2	0.034	41.0	46.0	7.13	0.025	0.74	11.50	0.026	0.76
3-Q- 5	0.013	16.5	23.0	2.87	0.004	0.31	5.75	0.005	0.38
3-Q-10	0.009	5.8	11.0	1.00	0.000	0.00	2.75	0.001	0.11
3-Q-20	0.007	0.0	0.0	0.00	-0.002	-0.29	0.00	-0.001	-0.14
7-Q- 2	0.036	42.8	50.0	7.43	0.027	0.75	12.50	0.028	0.78
7-Q- 5	0.013	16.5	23.0	2.87	0.004	0.31	5.75	0.005	0.38
7-Q-10	0.009	5.8	11.0	1.00	0.000	0.00	2.75	0.001	0.11
7-Q-20	0.007	0.0	0.0	0.00	-0.002	-0.29	0.00	-0.001	-0.14
15-Q- 2	0.044	57.8	65.0	10.04	0.035	0.80	16.25	0.036	0.82
15-Q- 5	0.016	20.5	25.0	3.57	0.007	0.44	6.25	0.008	0.50
15-Q-10	0.011	13.3	18.0	2.30	0.002	0.18	4.50	0.003	0.27
15-Q-20	0.009	5.8	11.0	1.00	0.000	0.00	2.75	0.001	0.11
30-Q- 2	0.057	68.0	77.0	11.83	0.048	0.84	19.25	0.049	0.86
30-Q- 5	0.019	23.5	28.0	4.09	0.010	0.53	7.00	0.011	0.58
30-Q-10	0.013	16.5	23.0	2.87	0.004	0.31	5.75	0.005	0.38
30-Q-20	0.011	13.3	18.0	2.30	0.002	0.18	4.50	0.003	0.27

APPENDIX I

AMMONIA TOXICITY RESEARCH AND ITS RELATION TO THE DEFINITION OF THE BIOLOGICALLY-BASED DESIGN LOW FLOW

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AMMONIA TOXICITY RESEARCH AND ITS RELATION TO THE DEFINITION OF THE BIOLOGICALLY-BASED DESIGN LOW FLOW

I.1 Literature Review and Review of Water Quality Criteria

a) Criteria with Other Agencies

The current MOE (1984) and the Province of Manitoba (1983) water quality objective for un-ionized ammonia is 0.02 mg/l for the protection of aquatic life (refer to Appendix G). This criteria was based on the lowest acute lethal concentration for rainbow trout (*Salmo gairdneri*) and Atlantic salmon (*Salmo salar*) (a mean concentration of 0.4 mg/l multiplied by a 0.05 safety factor).

The International Joint Commission (1986) has recently revised its criterion from 0.02 mg/l to 0.03 mg/l un-ionized ammonia. A review of lethal and sublethal effects of ammonia on biota found that the most sensitive response was for growth of salmonids. The highest concentration for which there was no effect on salmonid growth was 0.03 mg/l un-ionized ammonia. Laboratory studies also revealed that tolerance to ammonia by fish was related to duration of exposure. Brown et al (1969) and Thurston et al (1981a) found that fish could tolerate potentially lethal ammonia concentrations for short periods of time (<96 hours) with little or no sublethal effects. With this in mind, the IJC (1986) recommended higher ammonia criteria for areas where limited use zones mix with zones of passage. In these areas ammonia criteria would be determined by the pH related equation developed by Emerson (1982).

The U.S. EPA ammonia criteria varies with pH, temperature and sensitivity of the fish species. The U.S. EPA uses two different formulae to calculate 1) a short-term concentraion (1 hr average) and 2) a long-term concentration (4 day average) (see Appendix G).

G). The 1 hour average is derived from acute tests and the 4 day average is derived from chronic tests or where such data is lacking from predicted chronic effect concentrations based on expected chronic:acute ratios.

The recent Environment Canada ammonia guidelines (CCREM, 1987) have adopted the U.S. EPA (1985) 4 day un-ionized ammonia average criteria since the U.S. EPA values were derived from the largest and most up-to-date review. In addition, the criteria takes into consideration the effects of temperature and pH on the toxicity of ammonia to aquatic life.

The European ammonia criteria (EIFAC, Alabaster and Lloyd, 1982) is set at 0.025 mg/L un-ionized ammonia. The criteria should not be applied to temperatures below 5°C or to pH values above 8.0. The rationale for this criterion was the effect of un-ionized ammonia on salmonids. Adverse effects to salmonids caused by prolonged exposure were present at concentrations greater than 0.025 mg/L. Although fish species differed in their tolerance to ammonia, EIFAC did not find the difference great enough to justify different criteria for different species.

b) Ammonia Sources

Ammonia is present in most surface waters, groundwater and wastewaters as a normal product of organic decomposition. Bacterial oxidation converts ammonia into nitrates and nitrites. Under anaerobic conditions nitrate may be reduced to ammonia naturally (ALPHA, 1975). Another natural source is the excretion of ammonia by biota.

Anthropogenic sources such as sewage effluents, industrial effluents and agricultural fertilizer applications are the major contributors of ammonia into surface waters (Alabaster and Lloyd, 1980). Contributions through precipitation and gas exchange with the atmosphere also occur (IJC, 1986).

In freshwaters an equilibrium exists between ammonia gas, ammonium ion (NH4) and un-ionized ammonia (NH3). The equilibrium is expressed as:

$$\begin{aligned} NH_3 + H_2O \quad & NH_3 * H_2O\ (aq) \\ & NH_4 + (aq) + OH- \ (aq) \end{aligned}$$

The equilibrium between the ammonium ion and un-ionized ammonia depends upon the hydrogen ion concentration. As the pH increases (hydrogen ion concentration decreases), the equilibrium shifts in favour of the un-ionized ammonia such that a greater percentage of total ammonia (NH3 + NH4) is present as un-ionized ammonia (Laws, 1981). Also, as temperature increases the equilibrium between un-ionized and ionized ammonia shifts towards un-ionized ammonia. This combined influence has been described by Emerson et al (1975). Therefore, increases in solution pH and/or temperature tend to increase aquatic toxicity.

The toxicity of aqueous ammonia is mainly due to the un-ionized ammonia concentration.

c) Summary of Acute and Chronic Toxicity

The U.S. EPA (1985) found that un-ionized ammonia was acutely toxic to freshwater organisms at concentrations ranging from 0.53 to 22.8 mg/L for 19 invertebrate species representing 14 families and 16 genera and from 0.083 to 4.60 mg/L for 29 fish species from 9 families and 18 genera (see Appendix E). Salmonids were slightly more sensitive to un-ionized ammonia than non-salmonids. The lowest 96 hr LC50's for salmonids was 0.083 mg/L compared to 0.143 mg/L for non-salmonids (Rice and Bailey, 1980; Thurston and Meyn, 1984). Lower LC50 values indicate greater toxicity.

The size of fish and the length of exposure were important factors in determining water quality criteria. The majority of reported

LC50's are for 96 hours. For longer exposures the lethal threshold values declined (Thurston et al, 1978) resulting in a lower critical ammonia value. Larger rainbow trout (1-2.5 kg) are twice as sensitive to un-ionized ammonia as smaller trout (1-10 g) (Thurston and Russo, 1983).

In the field, fish mortality has been attributed to increased ammonia levels following industrial effluent discharge (Tarazona et al, 1987). In Canada studies involving caged fish placed in waters receiving sewage treatment effluents reported fish mortalities (Servizi and Martens, 1974; Flood et al, 1984; Fava et al, 1985). In studies of non-chlorinated sewage treatment plant effluents in Canada ammonia was the most commonly cited cause of increased lethality (Fava et al, 1985). It should be noted, however, that un-ionized ammonia was rarely calculated as a result of lacking information on total ammonia, pH or temperature.

Among freshwater biota, fish are generally more sensitive than invertebrates, with the possible exception of the fingernail clam. There does not appear to be any great difference in sensitivities between fish species. The mountain whitefish (Prosopium williamsoni), golden shiner (Notemigonus crysoleucas), orange-throat darter (Etheostoma spectabile), walleye (Stizostedion vitreum) and rainbow trout were equally sensitive species. The lowest 96 hr LC50 for rainbow trout was 0.16 mg/L un-ionized ammonia.

Signs of acute toxicity to fish included loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake resulting in convulsions, coma and finally death (U.S. EPA, 1985).

The U.S. EPA (1985) found that chronic toxicity occurred at un-ionized ammonia concentrations as low as 0.304 mg/L for two freshwater invertebrate species (Daphnia: refs) and as low as

0.0017 mg/L for nine freshwater fish species from 5 families and 7 genera (Rice and Bailey, 1980) (Appendix E).

Fish eggs appear to be less sensitive to un-ionized ammonia than juvenile and adults (Rice and Stokes, 1975). There was no growth impairment in salmonids for concentrations ranging from 0.017 to 0.07 mg/L (Smith, 1972; Robinson-Wilson and Seim, 1975; Thurston et al, 1984).

Under field conditions, Carline et al, (1987) found exceedances of the U.S. EPA ammonia criteria of 0.016 mg/L (0.004 to 0.055 mg/L un-ionized ammonia) resulted in gill damage which could be directly related to effluent ammonia concentrations.

Among freshwater biota, again fish appear to be more sensitive than invertebrates. There is no clear trend in chronic toxicity between different fish species (U.S. EPA, 1985).

At low concentrations ammonia may affect hatching success (Burkhalter and Kaya, 1977), growth rate (Smith, 1972), and morphological development of fish (Smart, 1976); Larmoyeux and Piper, 1973). Pathological changes may occur in gill, liver and kidney tissue (Thurston et al, 1984; Burrows, 1964). Sublethal levels of ammonia can also increase susceptibility to bacterial infection, respiratory and cardiac hyperactivity (IJC, 1986) and lower energy output (Westlake et al, 1983).

d) Environmental Factors Affecting Toxicity

Toxicity of un-ionized ammonia may be affected by shifts in the aqueous ammonia equilibrium as a result of changes in pH and/or temperature. Toxicity may also be enhanced or ameliorated by environmental factors such as dissolved oxygen, exposure to ammonia, carbon dioxide concentration and the presence of other toxicants.

i) pH and Temperature

The toxicity of ammonia is directly related to the concentration of un-ionized ammonia present in the water. This relationship is dependent upon pH and may be expressed by the following formulae; (Emerson et al, 1975)

$$\frac{1}{1 + 10^{(pKa - pH)}}$$

where $pKa = 0.09 + 2730/\ (273 + T)$
and $T = °C$

Therefore, as pH increases the acute toxicity of un-ionized ammonia increases. This relationship also holds for chronic toxicity although the amount of data available is considerably less than for acute toxicity.

Herbert (1962) and Woker (1949) found that survival of fish decreased with increases in temperature at constant levels of un-ionized ammonia concentrations although the threshold LC50's remained constant. Below 10°C Brown (1968) found the threshold LC50 decreased for rainbow trout. If ammonia concentrations rise in the winter as a result of either low flow or insufficient nitrification of sewage treated effluents, the increased toxicity during lower temperatures becomes important.

ii) Dissolved Solids

Messer et al (1984) found that un-ionized ammonia may be overestimated by as much as 10-20% in waters with high levels of dissolved solids (e.g. 600-1600 mg/L). As total dissolved solids concentration increases percent un-ionized ammonia decreases. In most freshwaters the effect of varying ionic strength is negligible. For the Great Lakes the effect of dissolved solids is less than that of changing the temperature by 1°C (Whitfield, 1978).

iii) Dissolved Oxygen

The acute toxicity of ammonia to fish increases as dissolved oxygen concentrations decrease. Merkens and Downing (1957), Lloyd (1961), Alabaster et al (1979) and Thurston et al (1981b) found varying increased sensitivities to ammonia when dissolved oxygen was reduced. No quantitative relationship between dissolved oxygen saturation and un-ionized ammonia concentrations has been developed.

iv) Carbon Dioxide Concentration

Increasing the level of free carbon dioxide in water reduces the pH value of the water thereby increasing toxicity. More importantly, Lloyd and Herbert (1960) suggested that it was the difference in pH values across the gill surface that determined toxicity to ammonia. For those species of fish with high respiratory efficiency (e.g. salmonids excrete relatively large amounts of carbon dioxide), un-ionized ammonia may be more toxic than for species with low respiratory efficiency.

v) Previous Exposure

Previous acclimation of fish to sublethal ammonia concentrations enables the fish to withstand potentially lethal concentrations. Fish are also more tolerant of constant concentrations of ammonia than fluctuating concentrations. There is evidence to suggest that fish will actively avoid lethal concentrations of ammonia where possible (Westlake et al, 1983; Jones, 1948; Summerfelt and Lewis, 1967) although there is no evidence to suggest that fish will avoid sublethal ammonia concentrations.

I.2 Case Study

Stations were chosen which had adequate flow record length of approximately 20 years and adequate water quality and biota information. The stations which were analysed were those where regular effluent releases are permitted. Effluent toxicity may result from ammonia, chlorine, hydrogen sulfide and metals, as well as other toxic components such as surfactants and organics. Possible toxicants for which there was sufficient water quality data included ammonia and select metals (cadmium, lead, zinc).

The parameter with the most extensive water quality data base was ammonia. Possible sources of error with the water quality data base included total ammonia anomalies prior to August, 1983 as a result of lengthy delays in sample analysis encountered during M.O.E.'s laboratory modernization in the early 1980's (G. Bowen, pers. comm.). In addition, the sampling schedule was not consistent within or between rivers. Generally water samples were taken a maximum of once a month. Data to determine variability within a day or month was lacking. Very often the un-ionized ammonia could not be calculated as either total ammonia concentrations, field pH or field temperature was missing.

If another parameter was to be considered, the frequency and duration would again have to be determined on toxicological and ecological data regarding that parameter. When more than one parameter is considered, whole effluent toxicity tests are administered to determine the site specific frequencies and duration. The advantages to chemical specific frequencies and durations include designing treatment systems to meet specific chemical requirements, potential modelling of the fate of the chemical and a requirement for only chemical testing rather than toxicity testing which can be very expensive. The disadvantages are that toxicants in wastewaters may not be characterized fully, the toxic component may not be known and the behaviour and combined toxic effect of a combination of chemicals is difficult to predict.

Past water quality data and the presence or absence of sensitive fish species were considered for the selected Ontario rivers in determining the frequency of CCC and CMC (summarized in Appendix G). Un-ionized ammonia concentrations were calculated from recent water quality data (post-August 1983). Where such data was insufficient (n <30), the whole water quality data base was examined. Based on ammonia criteria set out by MOE and U.S. EPA (summarized in Appendix G) most of the rivers were determined to be unstressed. Numerous exceedances of ammonia criteria had occurred in Grindstone Creek, the Don River and the Holland River (see table in Appendix G). Of the three rivers, the Don River appeared to have exceedances of ammonia criteria occurring for extended periods of time. The three rivers though were all classified as having present warm water fish species which are not as sensitive to ammonia concentrations as cold water species.

APPENDIX J

APPLICATION OF WASTE LOAD ALLOCATION USING MOE AND U.S. EPA METHODOLOGIES FOR SELECTED RIVERS IN ONTARIO

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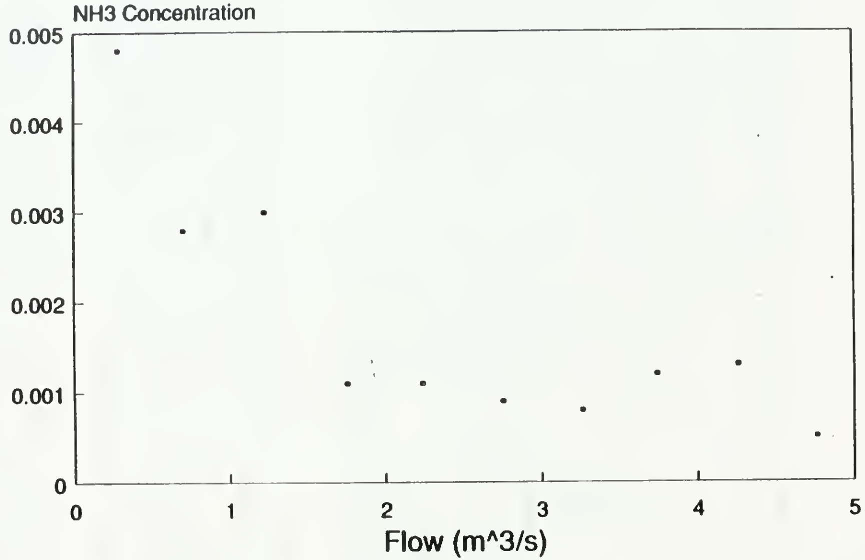
J.1 General

At the present time, the M.O.E. uses steady state modelling in its calculation of WLA's for pollutants. As such, the assumption is made that the discharge of pollutants is completely mixed with the receiving water. Before effluent concentration and flow rate are calculated for a particular wasteload allocation, the background ammonia concentrations must be known in order not to exceed provincial criteria with the addition of effluent concentrations. Varying background concentrations will result in either having to constantly determine the acceptable effluent concentration and flow rate or having to take the chance at exceeding the criteria. Alternatively, if a relationship exists between flow and background concentration, this relationship can be utilized in proper determination of wasteload allocation.

A preliminary investigation into establishing a relationship between streamflow and background ammonia concentrations was undertaken. Plots of un-ionized ammonia concentrations versus flow were created for each of the stations. From the plots it was evident that the inverse relationship to be expected between flows and concentration could be recognized for most rural watersheds.

The entire water quality and hydrometric data bases were combined. Rivers which had ammonia concentrations which exceeded current M.O.E. water quality objectives were eliminated from further analysis. The combined data base was then sorted into groups with a range of 0.5 m^3/s for flows between 0-5 m^3/s, and at larger increments for the entire data base. The mean concentrations were then determined for the grouped data, and plotted against the mean of the grouped flow range (Figures J.1a and J.1b). From these

Mean Conc. vs Mean Flow
Using Flow Intervals of 0.5 m^3/s



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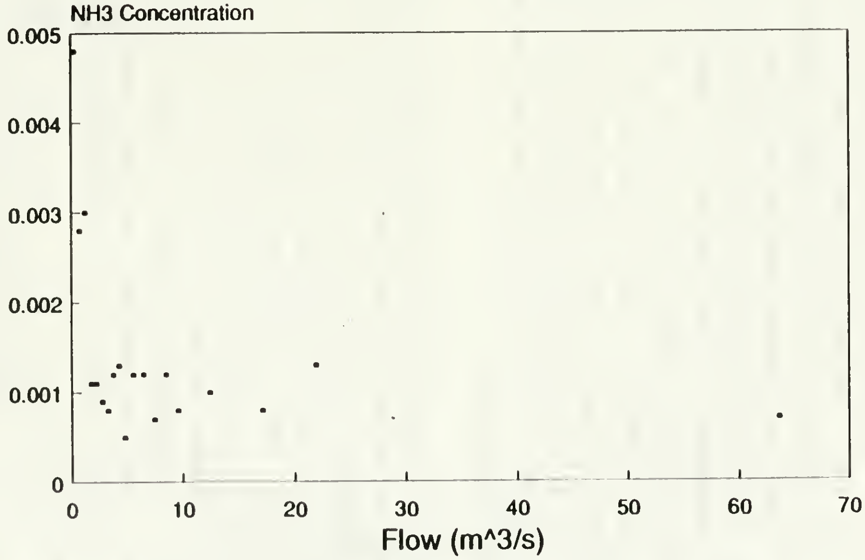
MEAN UN-IONIZED AMMONIA CONCENTRATION Vs FLOW.

FIGURE J.1a

Mean Conc. vs Mean Flow
Using Grouped Flow Data



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MEAN UN-IONIZED AMMONIA
CONCENTRATION Vs FLOW

FIGURE J.1b

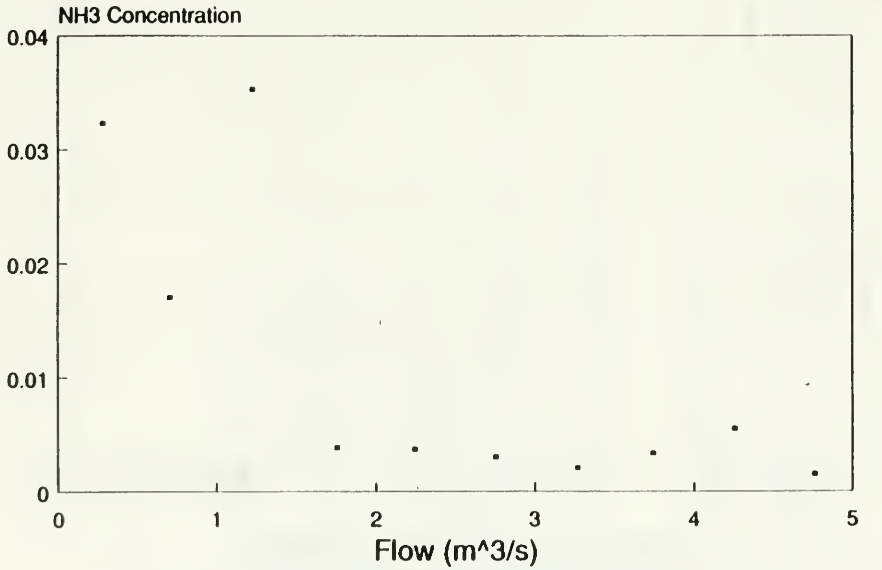
plots it appears that it may be possible to establish a relationship between background ammonia concentrations and flows under 5 m^3/s (in the range which is critical for most wasteload allocation calculations). The data base, however, was limited and analysis would have to be carried out on a larger data base before a firm and reliable relationship could be established. For example, the upper 95% confidence bounds of mean concentrations for the grouped data (presented in Figure J.2a and J.2b) represent values approximately four times the mean concentrations. Using a larger data base may significantly reduce the variance of the ammonia concentrations and result in smaller bounds for confidence limits. It may also be more reasonable to identify a quantity versus quality relationship on a more conservative and non-temperature, non-pH dependent pollutant.

Another consideration which should be made concerning wasteload allocation is the daily variation in receiving water and effluent flow combined with daily variation in effluent toxicity. Such characteristics can be considered by application of a probabilistic dynamic model. It is highly unreasonable to expect the worst case conditions, which are inherent in the steady state models for reasons of conservation, to occur with any great frequency or duration. Incorporating the appropriate probability distributions in place of the worst case conditions (while adequately considering the risk) will result in a more cost-effective and rational wasteload allocation.

J.2. Case Study for Comparing Permissible Pollutant Loading Rates for Waste Load Allocation

The U.S. EPA recommends the use of a combination of criteria which define 1) the criterion continuous and criterion maximum pollutant concentrations, and 2) the biologically based design low flows for wasteload allocation. The MOE currently advocates the use of the $7Q_{20}$ low flow criteria and the "Blue Book" pollutant loading

95% Upper Conc. Bound vs Mean Flow
Using Flow Intervals of 0.5 m^3/s



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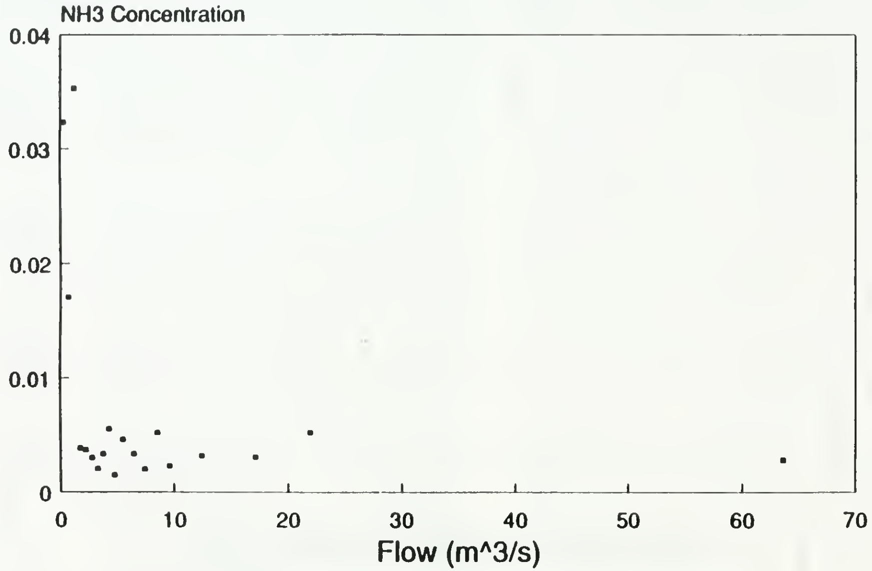
95% UPPER CONFIDENCE
BOUNDS FOR MEAN
UN-IONIZED FLOWS

FIGURE J-2a

95% Upper Conc. Bound vs Mean Flow Using Grouped Flow Data



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95% UPPER CONFIDENCE BOUNDS FOR MEAN UN-IONIZED FLOWS

FIGURE J-2b

objectives for waste load allocation. To evaluate the stringency of the MOE's water quality management standards, the net loading rates for the two techniques were compared.

Table J.1 summarizes the calculation of net pollutant loading rates and differences for 22 stations. The U.S. EPA Criterion Continuous Concentrations are averages for each station based on available temperature and pH measurements. The results indicate that, on a watershed basis, the current MOE standards are more stringent than the biologically-based U.S. EPA standards.

The results of the investigation concerning pollutant loading rates indicate that under current MOE design standards, wasteload allocation requirements are on average, approximately 25% more conservative than the U.S. EPA's methodology based on biological criteria. For 21 of the 22 stations where permissible pollutant loading rates were determined, the MOE standards were more conservative than the EPA's. The fact that one of the stations, under current MOE standards, results in greater permissible loading rates than the biological methodology would permit suggests that it may be prudent to extend the investigation to all rivers to identify locations which, due to local conditions, may unknowingly be exposed to stress.

Table J.1 Comparison of Net Pollutant Loading Rates Using MOE and U.S. EPA Methodologies

Flow Station	River Name	CCC Flow (m^3/s)	CCC Conc. (mg/l)	NH3 Load (mg)	7Q20 Flow (m^3/s)	MOE Conc. (mg/l)	NH3 Load (mg)	Diff. in Loading (mg)	Diff. as % CCC Load	Diff. as % MOE Load
02HC018	Lynde Creek	0.04	0.024	0.96	0.04	0.020	0.80	0.16	0.17	0.20
02HD008	Oshawa Creek	0.27	0.024	6.48	0.29	0.020	5.80	0.68	0.10	0.12
02HD009	Wilmot Creek	0.25	0.024	6.00	0.23	0.020	4.60	1.40	0.23	0.30
02HD010	Shelter Valley Brook	0.21	0.025	5.25	0.20	0.020	4.00	1.25	0.24	0.31
02HB012	Grindstone Creek	0.04	0.032	1.28	0.04	0.020	0.80	0.48	0.38	0.60
02GA018	Nith River	0.12	0.030	3.60	0.11	0.020	2.20	1.40	0.39	0.64
02ED007	Coldwater River	0.76	0.021	15.96	0.78	0.020	15.60	0.36	0.02	0.02
02EC009	Holland River	0.14	0.027	3.78	0.15	0.020	3.00	0.78	0.21	0.26
02EC011	Beaverton River	0.11	0.026	2.86	0.12	0.020	2.40	0.46	0.16	0.19
02HC025	Etobicoke Creek	0.62	0.030	18.60	0.59	0.020	11.80	6.80	0.37	0.58
02HC033	Mimico Creek	0.05	0.027	1.35	0.05	0.020	1.00	0.35	0.26	0.35
02HC025	Humber River	0.62	0.022	13.64	0.59	0.020	11.80	1.84	0.13	0.16
02HC009	East Humber River	0.08	0.023	1.84	0.08	0.020	1.60	0.24	0.13	0.15
02HC024	Don River (Lakeshore Blvd.)	1.13	0.024	27.12	1.16	0.020	23.20	3.92	0.14	0.17
02HC024	Don River (Bayview Exit)	1.13	0.022	24.86	1.16	0.020	23.20	1.66	0.07	0.07
02HC013	Highland Creek	0.08	0.025	2.00	0.08	0.020	1.60	0.40	0.20	0.25
02GG005	Sydenham River	0.08	0.025	2.00	0.19	0.020	3.80	-1.80	-0.90	-0.47
02GE005	Dingman Creek	0.01	0.023	0.23	0.01	0.020	0.20	0.03	0.13	0.15
02GC010	Big Otter Creek	0.32	0.029	9.28	0.31	0.020	6.20	3.08	0.33	0.50
02GC018	Catfish Creek	0.05	0.043	2.15	0.05	0.020	1.00	1.15	0.53	1.15
02FA001	Sauble River	0.63	0.025	15.75	0.57	0.020	11.40	4.35	0.28	0.38
02FC002	Saugeen River	3.88	0.027	104.76	3.95	0.020	79.00	25.76	0.25	0.33